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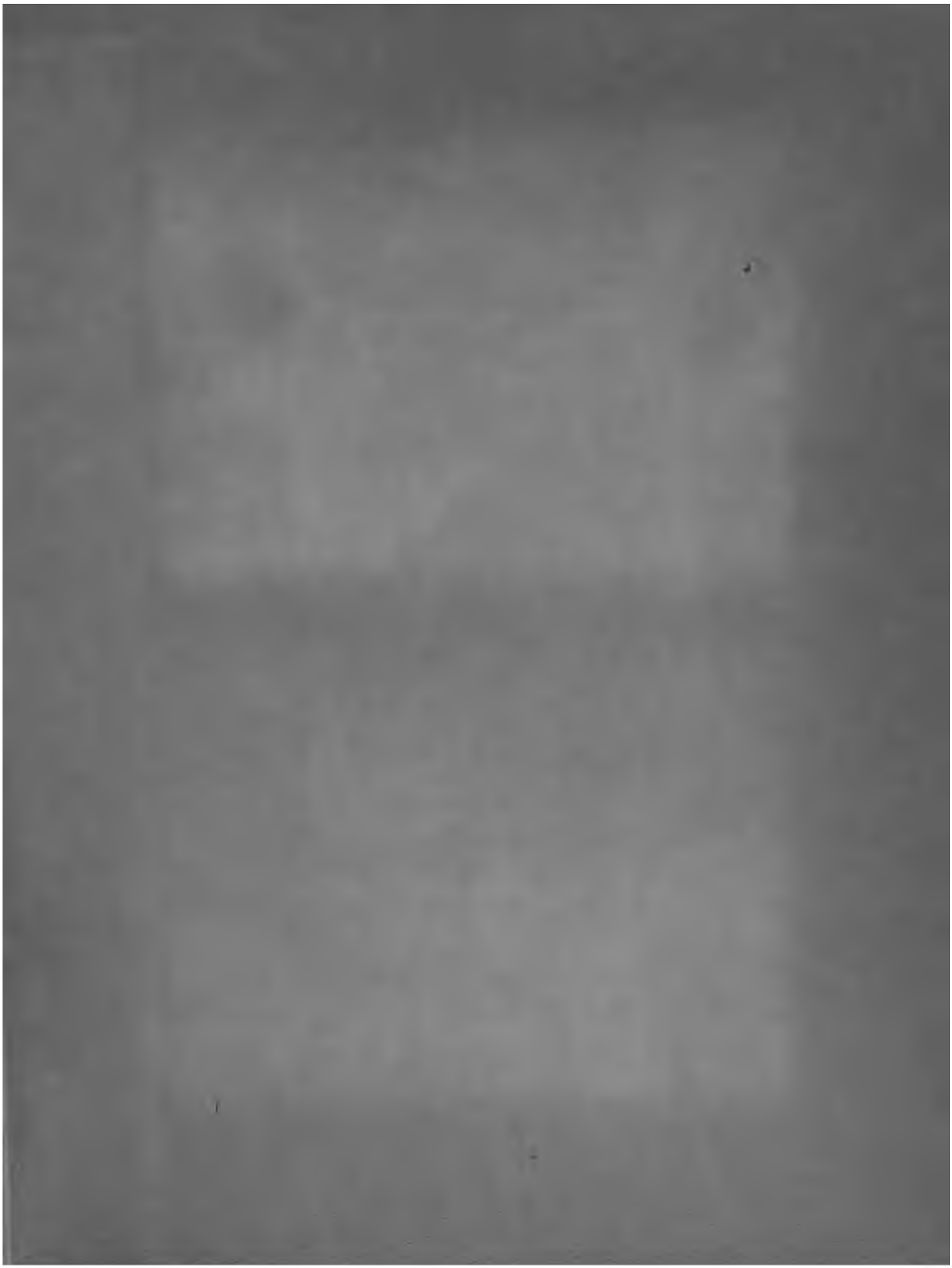

Professional Paper No. 33 Series H, Forestry, 11

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

FOREST CONDITIONS

IN THE

LINCOLN FOREST RESERVE, NEW MEXICO

BY

FRED. G. PLUMMER AND M. G. GOWSELL

WASHINGTON
GOVERNMENT PRINTING OFFICE
1904

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., March 8, 1904.

SIR: I transmit herewith for publication in the series of Professional Papers a report on forest conditions in the Lincoln Forest Reserve, in New Mexico, prepared by Messrs. Fred. G. Plummer and M. G. Gowsell.

Very respectfully,

HENRY GANNETT,
Geographer.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

FOREST CONDITIONS IN THE LINCOLN FOREST RESERVE, N. MEX.

By Fred. G. Plummer and M. G. Gowsell.

BOUNDARIES.

The Lincoln Forest Reserve, New Mexico, was created by proclamation of the President dated July 26, 1902, the description of the included area being given by townships and subdivisions as follows:

"Township seven (7) south, ranges eleven (11) and twelve (12) east, New Mexico principal meridian, New Mexico; sections thirteen (13) to thirty-six (36), both inclusive, township seven (7) south, range thirteen (13) east; township seven (7) south, ranges fourteen (14) and fifteen (15) east; sections thirteen (13) to thirty-six (36), both inclusive, township seven (7) south, ranges sixteen (16) and seventeen (17) east; township eight (8) south, ranges eleven (11) and twelve (12) east; sections one (1) to ten (10), both inclusive, and fifteen (15) to eighteen (18) both inclusive, township eight (8) south, range thirteen (13) east; sections one (1) to twenty (20), both inclusive, and the north half of sections twenty-nine (29) and thirty (30), township eight (8) south, range fourteen (14) east; township eight (8) south, ranges fifteen (15), sixteen (16), and seventeen (17) east; township nine (9) south, ranges ten (10), eleven (11), and twelve (12) east; township nine (9) south, range seventeen (17) east; township ten (10) south, ranges nine (9), ten (10), eleven (11), and twelve (12) east; sections seventeen (17) to twenty (20), both inclusive, and twenty-nine (29) to thirty-two (32), both inclusive, township ten (10) south, range thirteen (13) east; township eleven (11) south, range nine and one-half (9½) east; all of township eleven (11) south, range ten (10) east, which is not included in the Mescalero Apache Indian Reservation; sections five (5) to eight (8), both inclusive, sections seventeen (17) to twenty (20), both inclusive, and sections twenty-nine (29) to thirty-two (32), both inclusive, township eleven (11) south, range thirteen (13) east; township twelve (12) south, range ten (10) east; township thirteen (13) south, ranges ten (10) and eleven (11) east."

Petitions and recommendations for additions to this forest reserve cover the following areas: Portion of township 8 south, range 13 east; township 8 south, range 18 east; township 9 south, range 13 east; township 9 south, range 18 east; portion of township 10 south, range 13 east; township 10 south, range 14 east; township 10 south, range 15 east; portion of township 11 south, range 10 east;

township 11 south, range 11 east; portion of township 11 south, range 13 east; township 11 south, range 14 east; township 11 south, range 15 east; township 12 south, range 11 east; township 12 south, range 12 east.

All the areas above mentioned are described in this report and are shown on Pl. I (in pocket).

GENERAL DESCRIPTION.

In southern New Mexico, between the Rio Grande del Norte and the Rio Pecos, is an elevated region 140 miles wide, from the center of which rises an irregular mass of mountains whose summits and higher slopes are covered with timber, and whose lower declivities and spurs support a scattering woodland. Deciduous trees follow, or attempt to follow, for short distances, the water courses which radiate from these summits. There are four well-defined ranges—Sacramento Mountains, Sierra Blanca or White Mountains, Capitan Mountains, and Jicarilla Mountains. In the most southerly of these, the Sacramento Mountains, little of the land is owned by the Government, and the timber is being logged and marketed at Alamogordo, a station on the El Paso and Northeastern Railway 14 miles south of Tularosa. The southern portion of the Sierra Blanca is included within the present boundaries of the Mescalero Apache Indian Reservation. The remaining portions of these mountainous areas which are timbered, wooded, or important parts of watersheds are included in or are adjacent to the Lincoln Forest Reserve.

East of these mountains the surface slopes steadily to the Rio Pecos, but toward the west the slope is interrupted by the San Andreas Range and is not therefore directly tributary to the Rio Grande del Norte. The depression between the San Andreas Range and the area under consideration is arid and has no permanent surface drainage, the few small streams and springs immediately sinking into the earth. The Malpais, an ancient flood of lava which flowed from two craters, followed the central trough of the depression southward a distance of 40 miles to a point near the border of an ancient salt lake. This is a dry, unpromising region, without water or prospect of water for irrigation.

The general elevation of the region adjacent to the mountain ranges is 5,000 feet above the sea. The highest summit is Sierra Blanca Peak, which is in the northwest portion of the Mescalero Apache Indian Reservation, and which reaches an altitude of 11,882 feet. The axis of the range of the same name trends north and south from this summit. The Capitan Mountains bear east and west at right angles to the Sierra Blanca. Three low passes cut the mountains, but in other places the high relief is continuous.

Upon the higher slopes of the mountains are numerous small perpetual streams, varying in length according to the protection afforded by forest or woodland. Some of these unite to form "rivers," a term here applied to such

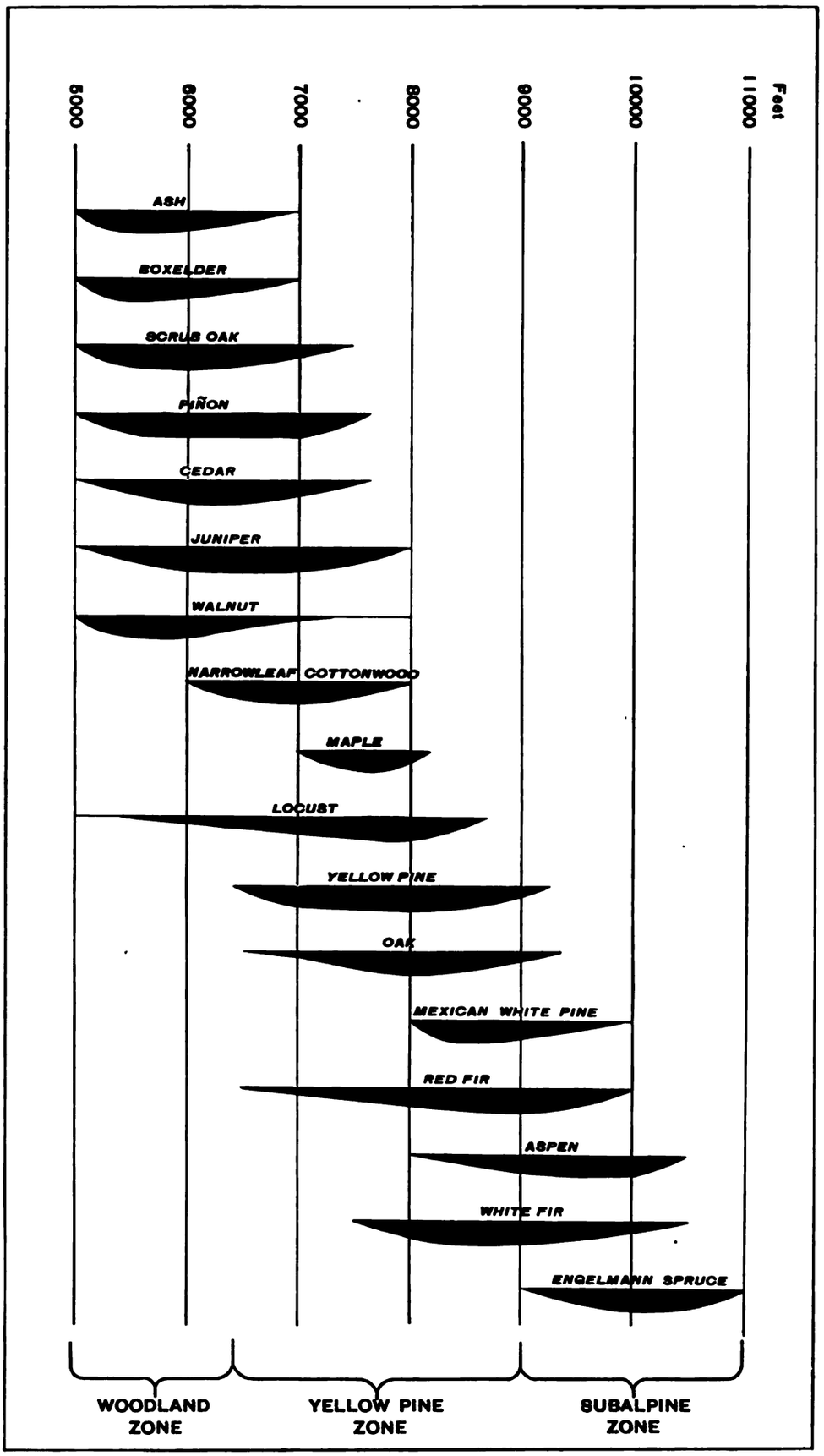


DIAGRAM SHOWING RANGE AND DEVELOPMENT OF TREE SPECIES.

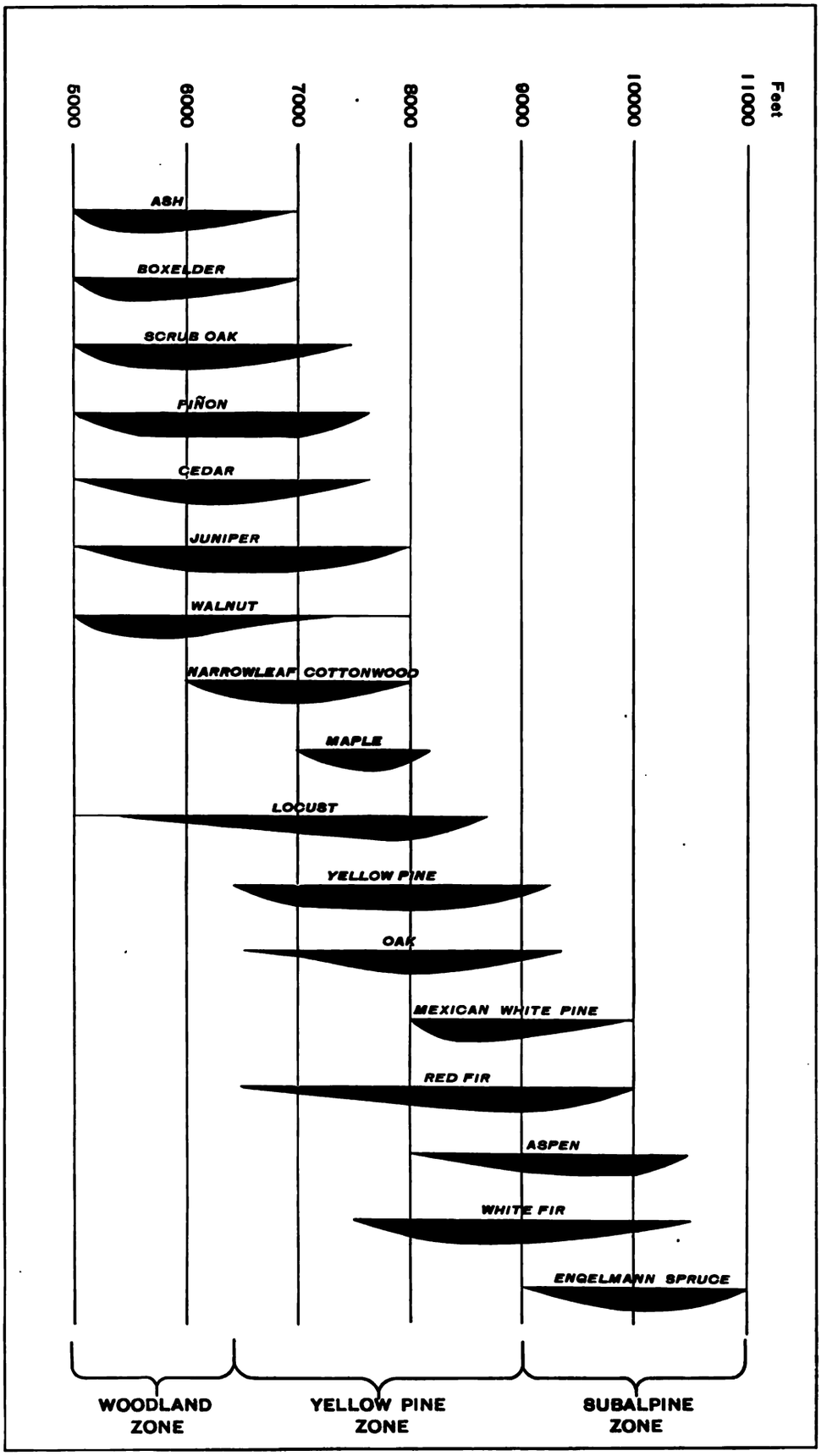


DIAGRAM SHOWING RANGE AND DEVELOPMENT OF TREE SPECIES.

of the watercourses as can advance a few miles desertward. These are mentioned more particularly under the heading "Irrigation" (pp. 16–18).

The El Paso and Northeastern Railway runs near the western boundary of the reserve. From Carrizozo a branch line crosses the mountains by Indian Pass and handles the output of the coal mines at Capitan. Wagon roads run everywhere over the flats, plains, and mesas, and the mountainous regions are accessible by numerous trails.

The forests are of a type common to the mountains of the Southwest—open and often scattered with light underbrush, almost lacking in humus except on some of the broad summits. Inasmuch as better lumber can be imported to the markets bordering this region, and as good water is the scarcest of commodities, these forests have their greatest value as water conservers.

FOREST ZONES.

For convenience, the areas in which timber and woodland growths are found may be divided into zones determined by altitudes, although these should not be considered as being clearly defined over the entire region examined. The ranges of the species vary greatly according to soil, moisture, and exposure, and only after a careful tabulation of all the data was the classification made. The custom of botanists and the precedent of former reports of this Survey on forest reserves make this method desirable, as it enables the relatively small and isolated forests under consideration to be compared with the forests in other regions.

The subalpine zone is found between altitudes of 9,000 and 11,000 feet. The principal tree is Engelmann spruce, with subordinate amounts of white fir, red fir, Mexican white pine, and aspen, generally in groves.

The yellow-pine zone ranges from 6,400 to 9,000 feet. The principal tree is yellow pine, with red fir, white fir, Mexican white pine, and oak. Along the streams and canyons are locust, maple, cottonwood, and other deciduous species overlapping from the woodland zone.

The woodland zone occurs between altitudes of 5,000 to 6,400 feet. The species composing it are piñon, juniper, cedar, scrub oak, and along streams ash, box elder, and walnut.

On the diagram, Pl. II, are shown the altitudinal ranges of these various species, and also, by the thickness of the figures, the elevation at which they reach best development.

Along Three Rivers, extending out into the desert about 10 miles beyond the lower limit of the woodland, is a narrow broken fringe of deciduous trees which deserves mention. The lands have long since passed from Government control, and there has been some culling among the trees for fuel. The best growth was

found near Three Rivers post-office, where an acre was measured and estimated as follows:

Number of trees on 1 acre near Three Rivers, N. Mex.

Species.	Diameter in inches.									
	2.	4.	6.	8.	10.	12.	14.	16.	18.	24.
Black walnut	1	5	1	4	2	5	6	2	1	....
Box elder	1	2	....	4	7	6	3	....	....	1
Ash	....	....	....	....	1	1	....	....	....	....
Locust	....	1	....	....	....	....	....	....	....	....

The trees fork low, are very crooked, and very little clear lumber could be cut from each. Nevertheless, such an exceptional acre would run over 1,000 feet B. M. The entire fringe of trees will not average 30 per cent of the above.

DESCRIPTIONS OF TREES.

Yellow pine (*Pinus ponderosa*).—This is the chief timber tree in both the Sierra Blanca and the Capitan mountains. It ranges between 6,400 and 9,250 feet elevation above the sea and forms 61 per cent of the entire forest stand. It rarely forms pure forests, being more or less associated with the woodland species at its lower range, and at higher elevations being mixed with all of the other timber species. The average mature tree has a height of 45 feet, with 11 feet of clear trunk and a diameter of 10 inches. Veterans attain a height of 100 feet and 30 inches in diameter.

Mexican white pine (*Pinus strobiformis*).—This species is found as a member of the mixed forests at the higher elevations throughout the reserve. It is a valuable timber tree for this locality, and in quality is considered second only to the yellow pine. It has been culled for lumber along the headwaters of Eagle Creek, and also along the western summits of the Capitan Mountains, where it has been worked for shingles under the local name of "sugar pine." It comprises 7 per cent of the entire forest stand. Average trees are 38 feet high, with 11 feet of clear trunk and 9 inches diameter. A few veterans reach a height of 100 feet and a diameter of 30 inches.

Piñon (*Pinus edulis*).—This piñon is the principal constituent of the woodland, and is frequently associated with yellow pine at the lower altitudinal range of the latter. It is a remarkably hardy tree, and is the leader in the slow advance of the woodland upon the bordering arid lands. Mature trees at higher elevations reach a height of 30 feet and have a diameter of 9 inches, but are

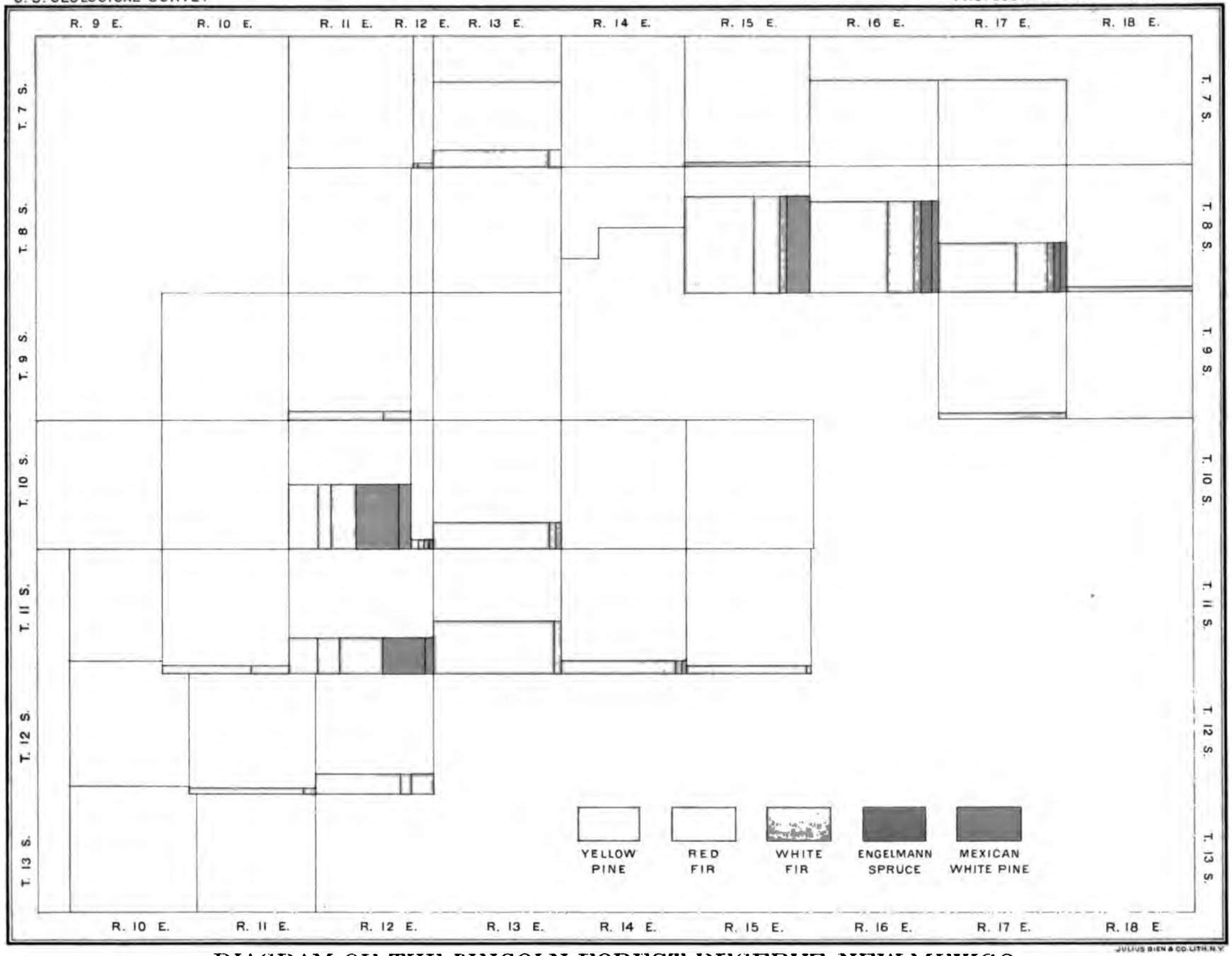


DIAGRAM OF THE LINCOLN FOREST RESERVE, NEW MEXICO

SHOWING STAND OF COMMERCIAL SPECIES OF TIMBER AND PROPORTION

JULIUS BIEN & CO. LITH. N.Y.

very crooked and are of use only for fuel. Once in about four years they set an abundance of cones, the seeds of which are edible.

Red fir (*Pseudotsuga taxifolia*).—This tree, the most important member of the heavy forests of the North Pacific coast, reaches in this locality a point near its eastern and southern limits of distribution. It is here an intruder on the domain of the yellow pine and the Engelmann spruce, and reaches a very inferior development when compared with localities where it ranks first in importance. The average mature tree is only 40 feet in height, with 8 feet clear trunk and a diameter of 8 inches, although veterans attain a diameter of 30 inches and a height of 90 feet.

White fir (*Abies concolor*).—This fir has a large altitudinal range, extending from 7,500 to 10,500 feet. Together with the red fir it is an important tree in the transition from the yellow-pine zone to the subalpine zone, and is estimated to form 8 per cent of the total forest stand. Its heavy foliage affords good shade and protection on the more elevated slopes and in most of the principal canyons. Mature trees reach a diameter of 34 inches, with a height of 85 feet, but the average is the same as of the red fir.

Subalpine fir (*Abies lasiocarpa*).—Foliage of this species was found, closely resembling the lower foliage of *Abies amabilis*, in T. 10 S., R. 11 E., but no cones could be obtained for its positive identification, although careful search was made. The trees were young and formed part of a new growth succeeding the dying Engelmann spruce.

Engelmann spruce (*Picea engelmanni*).—This species is limited to elevations above the 9,000-foot contour, where it frequently forms pure forests. The conditions for its best development are found along the high ridges north of Sierra Blanca Peak, at the headwaters of the Rio Ruidoso, and also along the broad summits of the Capitan Mountains. Notwithstanding the fact that the summits of the Sierra Blanca afford apparently ideal conditions for the growth of the spruce, about 20 per cent of the standing trees are dead or dying. This gives the forest the appearance of having been scorched by a fire not severe enough to utterly destroy it. For this no cause was found. The mature trees reach a diameter of 24 inches and a height of about 75 feet, with branches nearly to the ground.

Cedar (*Juniperus monosperma*).—This species (also called savin) is found throughout the wooded districts, and its altitudinal range is the same as that of piñon. It furnishes 13 per cent of the total estimated cord wood. Although it is a very scraggy tree, yet, owing to its ability to withstand ground rot, it is much prized for fence posts and rails. Mature trees attain a height of 20 feet and a diameter of 9 inches.

Alligator juniper (*Juniperus pachyphlœa*).—This is a valuable fuel tree, forming 30 per cent of the woodland. It has a greater altitudinal range than the piñon, being frequently found in the middle of the yellow-pine zone, where its position is generally on the open mountain sides or elevated mesas rather than in canyons or other waterways. Mature trees reach a diameter of 14 inches, but the average tree is about 4 inches in diameter and 15 feet in height. The trees are generally symmetrical and often beautiful, and their abundant crops of berries are considered edible after the first frosts of early winter.

Rocky Mountain oak (*Quercus undulata*).—This tree is common above an altitude of 7,000 feet, forming characteristic groves on otherwise timberless slopes or spurs, particularly in the Sierra Blanca region. It is also found along the summits of the Capitan Mountains, associated with timber species. It is usually about 15 feet in height, with 4 feet clear trunk, and a diameter of 3 inches, although veterans attain 40 feet in height and a diameter of 10 inches. It is afflicted with dry rot over the western end of the Capitan Mountain region.

Gambel oak (*Quercus gambelii*).—This small tree is common to nearly all of the woodland, being associated with the piñon and cedar. It is not in demand for any purpose except fuel or an occasional fence post.

Aspen (*Populus tremuloides*).—A common tree in the subalpine zone, where it is frequently found in isolated groves, which, in every instance, appear to be restockings of very old burns. On the north side of Sierra Blanca and among the dying spruce this species is doing considerable restocking. In T. 8 S., R. 16 E., it comprises about 20 per cent of the forest cover in the subalpine zone. Average trees attain a height of 30 feet, 10 feet clear trunk, and a diameter of 6 inches.

Narrow-leaf cottonwood (*Populus angustifolia*).—This species is represented along nearly all streams, where it forms a part of the mixed forests. It thrives best at about 7,000 feet elevation, but has been cultivated at lower altitudes. The average tree is 40 feet in height, having 10 feet clear trunk and a diameter of 9 inches.

Fremont cottonwood (*Populus fremontii*).—This tree is found in the cultivated districts throughout the reserve, chiefly along irrigating ditches, where it is a very serviceable shade tree.

Mexican walnut (*Juglans rupestris*).—This tree is common to nearly all watercourses throughout this region, and is found at its best along Three Rivers and the Rio Ruidoso. It has a more rapid growth than any other tree found in the reserve. Average trees reach a height of 40 feet and a diameter of 11 inches, with 6 feet clear trunk.

A. SCRUB OAKS NEAR THREE RIVERS.

B. FREMONT COTTONWOODS ALONG IRRIGATING DITCH.

Box elder (*Acer negundo*).—The box elder is closely associated with Mexican walnut and other deciduous trees along the principal streams. The trunks are very crooked and would afford very little clear lumber. It is a beautiful shade tree. Average trees have a height of 40 feet, 4 feet clear trunk, and a diameter of about 9 inches.

Leather-leaf ash (*Fraxinus velutina*).—The leather-leaf ash is an uncommon tree in this region. It is much sought on account of its strength and endurance. It is found along Three Rivers and Eagle Creek, and also in the Capitan Mountains. The average tree reaches 35 feet in height, 7 feet clear trunk, and 10 inches in diameter.

Large-tooth maple (*Acer saccharum grandidentatum*).—This species is represented in the Capitan Mountains, in T. 8 S., R. 16 E., but is more common in Nogal Canyon, on the east slopes of the Sierra Blanca, at an altitude of 7,000 to 8,000 feet, where it is closely associated with aspen and other deciduous trees. It has been cut chiefly for cord wood. Mature trees attain a diameter of 10 inches and a height of 50 feet.

New Mexican locust (*Robinia neomexicana*).—This tree has an extensive distribution through this region. While small and unimportant for either timber or cord wood, it is very serviceable as a water conserver on some of the high eastern spurs of the Sierra Blanca, where, after the manner of the oak, it forms numerous small groves and thickets. It was seen at its best toward the head of Carrizo Creek, at an elevation of 8,300 feet, in T. 12 S., R. 12 E.

Rate of growth of trees in Lincoln Forest Reserve, N. Mex.

Species.	Radius.	Annual rings.	Year's growth per inch.
	Inches.		
Yellow pine	108.55	1,340	12.30
Mexican white pine	13.50	244	18.00
Piñon	4.95	168	34.00
Red fir	33.50	388	11.50
White fir	14.40	151	10.40
Alligator juniper	16.00	593	35.80
Large-tooth maple	17.35	390	22.40
Rocky Mountain (scrub) oak	9.11	167	18.30
Black walnut	9.92	54	5.44
Black ash	3.80	28	7.37

PRICES OF LUMBER.

West of the forest reserve, along the line of the El Paso and Northeastern Railway, the lumber is generally obtained in the Sacramento Mountains. East of the reserve, along the Pecos Valley and Northeastern Railway, the supply is obtained from Arkansas or from the Pacific coast. At Alamogordo the principal woods used are locally known as "red spruce" (*Pseudotsuga taxifolia*) and "mountain pine" (*Pinus ponderosa*). In this report they are referred to as "red fir" and "yellow pine." Prices of local and imported lumber do not vary materially and are as follows:

Prices of lumber in Lincoln Forest Reserve, N. Mex., per M feet B. M.

1 by 3, 1 by 4, 1 by 6, surfaced two sides	$26
1 by 8, 1 by 10, surfaced two sides	27
1 by 12, surfaced two sides	30
2 by 8, 2 by 10, surfaced two sides	29
2 by 12, surfaced two sides	32
1 by 4, 1 by 6, 1 by 8, surfaced one side	16
1 by 10, surfaced one side	17
1 by 12, surfaced one side	19
4 by 8 to 8 by 8, 4 by 10 to 12 by 12, surfaced one side	20
Flooring and ceiling	$20 to 26
Shingles, per 1,000	5
Laths, per 1,000	4

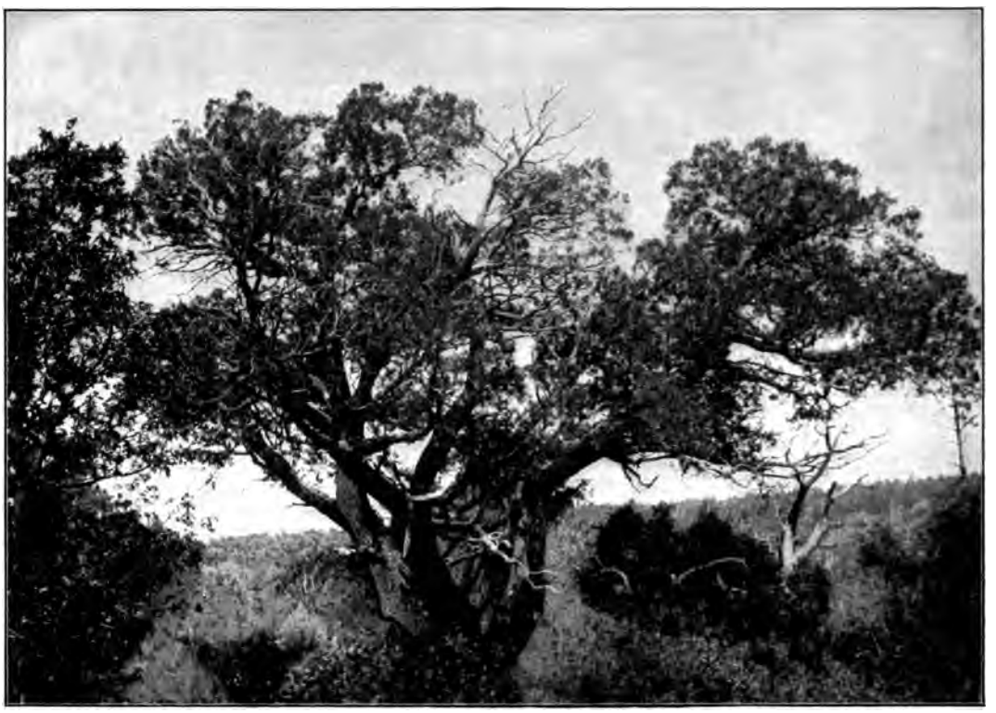
Heart stock brings $2.50 extra per M feet B. M.

IRRIGATION.

On all sides of the mountains are broad stretches of gently sloping plains and mesas, in which the soil, climate, and topography are favorable to agriculture, but the most important of all factors, water, is lacking. The Rio Bonito, Rio Ruidoso, and Rio Tularosa are the only streams which have a surface flow extending any considerable distance over the arid area, and none of their perpetual normal flow is permitted to waste. The cultivated lands in the area examined aggregate only 4,197 acres, an insignificant percentage of the enormous areas which could be irrigated if water could be secured.

Artificial "tanks" are frequently employed for the storage of intermittent surface flows where water is used for domestic purposes and irrigation, but no works have as yet been constructed for the impounding of flood waters for general distribution.

The Rio Tularosa furnishes the supply for the Mescalero Apache Indian Reservation Agency; also for the irrigation of several small farms outside of the reservation and for the town of Tularosa. There are about 150 claimants in Tularosa, to



A. ALLIGATOR JUNIPER IN THE WOODLAND.

B. YELLOW PINE AND WOODLAND.

whom a ditch tender apportions the water, the turn of each claimant recurring in about two weeks.

On Arroyo Rinconada, in T. 13 S., R. 10 E., is a promising location for a reservoir for the storage of the flood waters of this stream. Some preliminary surveys have been made by private parties, who hoped to reclaim about 20,000 acres of excellent land lying north of Tularosa, an area known locally as Temporal Flats.

Three Rivers, draining the high western slopes of Sierra Blanca, is now considered perpetual only as far as sec. 13, T. 11 S., R. 9½ E. According to old settlers, its surface flow formerly extended westerly into the desert about 15 miles beyond this point. The lands along its valley are well adapted for the growing of fruits and garden produce, and none of its surface flow is wasted.

Nogal Arroyo carries considerable water during flood seasons, but no attempts have been made to reclaim any of the Carrizozo Flats, the only irrigation practiced being near its source, in T. 9 S., R. 12 E., where its flow is perpetual. During the flood season in June, 1902, a large amount of water was held back by the grade of the El Paso and Northeastern Railway near the town of Carrizozo. According to the estimates of residents, the quantity was sufficient to have covered the flats to a depth of 2 inches had it been evenly distributed. There are two wells at Carrizozo—one alkaline, the other sulphurous. The water for drinking is brought from Alamogordo by railway tank cars.

Carrizo Creek does not furnish water for irrigation, but one of its tributaries, which heads in T. 8 S., R. 16 E., supplies water for stock the year round, and also serves for the irrigation of a patch of alfalfa belonging to the "Block ranch," in the northern part of T. 7 S., R. 16 E., outside of the forest reserve. Its waters are carried in an open ditch.

Burers Canyon, on the north slope of the Capitan Mountains, has a perpetual flow near its head, and furnishes water for the irrigation of about 10 acres near the southwest corner of T. 7 S., R. 17 E. In sec. 36 of the same township is a field of 10 acres, principally corn, irrigated by a small unnamed stream from the Capitan Mountains. The drainage from the eastern spurs of these mountains is used for the irrigation of a few small and unimportant areas in Ts. 8 and 9 S., R. 18 E., and it is probable that a careful survey would show some possibilities for the impounding of the flood waters of Bluewater and Blackwater canyons for use in arable areas farther east.

The Rio Bonito is important, furnishing water for irrigation and domestic supply throughout its length. It passes through the Fort Stanton Marine Hospital Reserve.

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Little Creek and Eagle Creek are of comparatively little importance, and the small perpetual flow at their heads is used only in T. 10 S., R. 13 E. There are some promising mesa lands bordering these streams, but so far their cultivation without water has not proved a success.

The Rio Ruidoso is important for irrigation outside of the present limits of the forest reserve and within the area shown on the map (Pl. I). It is partly for this reason that settlers have petitioned for the inclusion of this stream in the reserve.

GRAZING.

Over the greater portion of the forest reserve forage grasses form an important part of the ground cover. They are not only a factor in regulating the run-off after heavy rains or melting snows, but retard the excessive evaporation. The areas shown in yellow on Pl. I include only such grazing lands as support neither woodland nor timber, but all of the forest reserve might be classified as grazing land so far as its natural utility for that purpose is concerned. The elevated timberless spurs from the Sierra Blanca are well covered with forage grasses, and together with the forested summits of the Capitan Mountains are at present the best areas for stock grazing. The lower slopes and plains, lying below the 7,000-foot contour, have been more accessible, and for this reason have been irreparably damaged by overgrazing. In some places the extermination of the gramma grasses and other ground cover has permitted deep and extensive erosion, actually changing the topography and laying waste large areas which formally supported a luxuriant growth of valuable forage grasses. This effect was particularly noticed in the northwest portion of T. 10 S., R. 14 E., but is observable in the western tiers of townships, which include Carrizozo Flats, where the grazing value is very low as a result of overgrazing, and where the grasses will be extinct ere long. Mountain mahogany is plentiful in the Capitan Mountains and furnishes the principal winter browse.

BURNS.

The total burned area was estimated at 1,480 acres, or less than 1 per cent of the entire timbered area examined. The areas classified as burned include only such as are so recent as to contain no merchantable timber, and it must not be inferred that fires are of rare occurrence in this region. Very small burns are numerous, and considerable areas have been overrun by fires which resulted in the partial destruction of the trees. This is particularly true in the Capitan Mountains, where sapling conifers and scrub oak have been the greatest sufferers. Since the establishment of the forest reserve most of these small fires have ceased, owing partly to the vigorous patrol which has been

A. YELLOW PINES.

B. INCEPTION OF AN ARROYO IN AN OVERGRAZED AREA.

maintained, and also to the changed sentiment of the people, who are now fully alive to the benefits of forest protection.

Traces of very old burns are frequently seen throughout the timbered areas, particularly near the summits. In many cases the restocking has been by aspen (*Populus tremuloides*) where the original forest was undoubtedly coniferous.

T. 10 S., R. 11 E., has sustained the greatest loss from fires, which, according to the testimony of residents, have resulted in a visible decrease in the minimum flow of the streams. These burns occurred in 1895, as did also the burn in sec. 3, T. 11 S., R. 11 E. The resulting litter from these fires, together with the dead and dying Engelmann spruce, which is mentioned elsewhere in this report, is a constant menace to the standing forests, and will necessitate the utmost vigilance on the part of the rangers to prevent a most disastrous conflagration, the effects of which would be far-reaching for the reason that the most important streams rise in these townships.

MINING.

The area examined covers portions of eight mining districts—White Oaks, Vera Cruz, Nogal, White Mountain, Rio Tularosa, Tularosa, Capitan, and Bonito. The region has been well prospected for gold, silver, and copper, which have been found in paying quantities. A 15-stamp mill has been installed 2 miles south of Nogal town site to work the free-milling output from the Helen Rae, American, and adjacent properties. There has been considerable development work in the vicinity of Bonito and Parsons, where promising ledges of gold-bearing quartz have been uncovered in the porphyritic formations.

Measures of bituminous coal are found in the vicinity of Capitan, in T. 9 S., R. 14 E., and also near White Oaks. The former are being worked by the New Mexico Railway and Coal Company, and in 1901 yielded 200,000 tons.

Further details regarding these and other mining properties will be found in the report of the governor of New Mexico, 1902, page 523 et seq.

DESCRIPTIONS OF TOWNSHIPS.

Township 7 South, Range 11 East.

The eastern third of this township is steep and rocky, lying on the west slope of Carrizo Peak. The rest is a gently rolling and sloping plain, which supports neither woodland nor forest. The surface is cut by shallow arroyos which drain westerly to the Malpais. There has been much overgrazing, particularly in the southern portions. A goat ranch is located in sec. 24, where there is a small spring. In sec. 28 is a ranch with a well 50 feet deep giving good soft water. All the woodland is on the slopes of Carrizo Peak. The

reproduction is good, and there has been some culling for fuel in sec. 23. There is no timber.

Stand of trees in T. 7 S., R. 11 E.

	Cords.
Piñon	4,000
Juniper	1,600
Cedar	1,600
Oak	800
Total	8,000

Township 7 South, Range 12 East.

This irregular township contains but six sections. It lies on both sides of Carrizo Peak, which has an elevation of about 9,500 feet and a rough and precipitous surface. Only the higher elevations are timbered, the lower slopes being scattering woodland. It has been grazed by goats.

Stand of trees in T. 7 S., R. 12 E.

	Cords.	Feet B. M.
Yellow pine		643,000
Red fir		1,502,000
Piñon	2,280	.....
Juniper	1,140	.....
Cedar	380	.....
Total	3,800	2,145,000

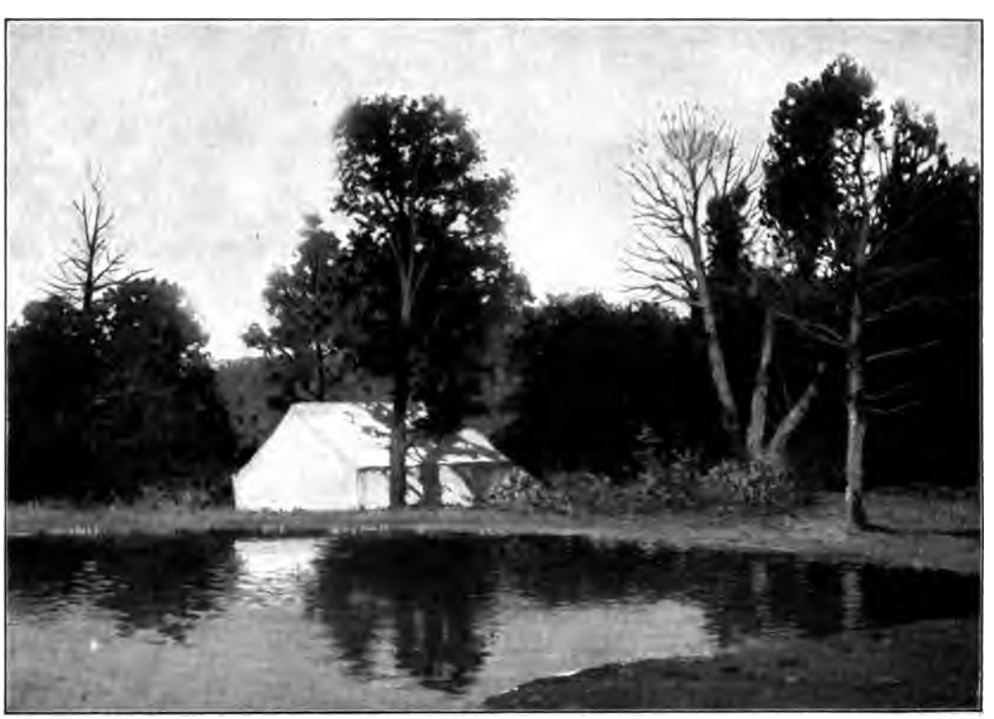
Conditions of timber trees in T. 7 S., R. 12 E.

Average total height	feet..	30
Average height, clear	do..	10
Average diameter, breast-high	inches..	12
Dead	per cent..	1
Average age	years..	70
Reproduction		Good.

Township 7 South, Range 13 East.

Secs. 13 to 36, inclusive, are within the reserve. The surface is rough and mountainous, traversed by a divide which has a general northwest-southeast trend, and is cut by Bernal Gap. The northeastern portion is cut by numerous arroyos which drain into Carrizo Creek. In the southwestern portion Bernal Gap drains into Nogal Arroyo. All the township has been grazed, principally by cattle. A small sawmill is operating intermittently on sec. 9, outside the

A. GROVE OF ROCKY MOUNTAIN OAKS.



B. ARTIFICIAL "TANK" FOR WATER SUPPLY.

Stand of trees in T. 7 S., R. 13 E.

	Cords.	Feet B. M.
Yellow pine		9,810,000
Red fir		1,090,000
Piñon	5,400	
Juniper	4,200	
Cedar	1,800	
Oak	600	
Total	12,000	10,900,000

Conditions of timber trees in T. 7 S., R 13 E.

Average total height	feet	50
Average height, clear	do	10
Average diameter, breast-high	inches	10
Dead	per cent	1
Diseased	do	1
Average age	years	60
Reproduction		Good.

Township 7 South, Range 14 East.

The surface is gently sloping and rolling toward the north and east and is drained by Carrizo Creek, the flow of which is perpetual in portions of its bed and sinks in others. In the creek valley are about 1,000 acres of arable land, of which 60 acres are in cultivation. The entire township has been grazed, principally by cattle. In the southern and western portions there has been some culling of the trees for fuel and fencing. In sec. 32 is a well, but the water is strongly impregnated with gypsum.

Stand of trees in T. 7 S., R. 14 E.

	Cords.	Feet B. M.
Yellow pine		560,000
Piñon	18,000	
Juniper	9,000	
Cedar	1,500	
Oak	1,500	
Total	30,000	560,000

Conditions of timber trees in T. 7 S., R. 14 E.

Average total height	feet	40
Average height, clear	do	10
Average diameter, breast-high	inches	8
Dead	per cent	2
Diseased	do	1
Average age	years	50
Reproduction		Medium.

Township 7 South, Range 15 East.

The surface has an easy gradient to the north and is drained by arroyos tributary to Carrizo Creek. It has all been closely grazed. In secs. 28 and 35 the water for domestic purposes and for watering stock has been piped a distance of 1½ miles. There is no other water in the township. A sawmill was formerly located in sec. 34, for which some culling was done in the canyons and arroyos in the immediate neighborhood.

Stand of trees in T. 7 S., R. 15 E.

	Cords.	Feet B. M.
Yellow pine		2,540,000
Piñon	19,350	.....
Juniper	21,500	.....
Oak	2,150	.....
Total	43,000	2,540,000

Conditions of timber trees in T. 7 S., R. 15 E.

Average total height	feet	40
Average height, clear	do	10
Average diameter, breast-high	inches	8
Dead	per cent	5
Diseased	do	1
Average age	years	50
Reproduction		Good.

Township 7 South, Range 16 East.

Secs. 13 to 36, inclusive, are within the reserve. The surface has a gentle slope to the north and is cut by numerous arroyos. A well 100 feet deep in sec. 22 furnishes an abundance of good water for a small settlement of Mexicans. The Block ranch, with headquarters at Richardson, in the northwestern part of this township, brings water a distance of over 6 miles through an open ditch from streams which head in the Capitan Mountains, in T. 8 S., R. 16 E. All this township is being grazed by cattle. Fifteen years ago portable sawmills operated in the canyons in the southern portion.

Stand of trees in T. 7 S., R. 16 E.

	Cords.	Feet B. M.
Yellow pine		1,120,000
Piñon	28,800	.....
Juniper	28,800	.....
Oak	6,400	.....
Total	64,000	1,120,000

Conditions of timber trees in T. 7 S., R. 16 E.

Average total height	feet	40
Average height, clear	do	10
Average diameter, breast-high	inches	8
Dead	per cent	5
Diseased	do	2
Average age	years	50
Reproduction		Medium.

Township 7 South, Range 17 East.

Secs. 13 to 36, inclusive, are within the reserve. The surface has a gentle slope to the north and east and is cut by a number of small arroyos. Water has been brought 5 miles by flume from sec. 15, T. 8 S., R. 17 E., and is used in sec. 26 for domestic and other purposes. All this township has been closely grazed by cattle, and also bears evidence of having been oversheeped in the past. In the southern part there has been some culling for cord wood and posts.

Stand of trees in T. 7 S., R. 17 E.

	Cords.	Feet B. M.
Yellow pine	.....	180,000
Piñon	27,500	.....
Juniper	16,500	.....
Cedar	2,750	.....
Oak	8,250	.....
Total	55,000	180,000

Conditions of timber trees in T. 7 S., R. 17 E.

Average total height	feet	40
Average height, clear	do	10
Average diameter, breast-high	inches	8
Dead	per cent	5
Diseased	do	3
Average age	years	50
Reproduction		Good.

Township 8 South, Range 11 East.

The northern portion of this township is a nearly level plain lying between Carrizo Peak and the northern end of the Sierra Blanca, known locally as Carrizozo Flats. The southern portion is steep and rocky and is cut by numerous deep arroyos which drain northwesterly toward the Malpais. There are some mining claims and a rancher in sec. 33, where there has been some culling for fuel. The entire township has been badly overgrazed and the ground cover ruined. Under these conditions it is not likely that the woodland, which extends into the southern

tier of sections, will naturally reclaim any of these areas, although the reproduction is good.

Stand of trees in T 8 S., R. 11 E.

	Cords.
Piñon	500
Cedar	500
Total	1,000

Township 8 South, Range 12 East.

This irregular township contains less than 7 sections. The surface is gently rolling valley land, which is tributary to Nogal Arroyo. There is no timber, and the only woodland is at the southern boundary.

Stand of trees in T 8 S., R. 12 E.

	Cords.
Piñon	250
Cedar	250
Total	500

Township 8 South, Range 13 East.

This township lies on the divide between the Rio Pecos and the Malpais desert, including in part the Vera Cruz Mountains and the Tucson Mountains, which reach an elevation of 8,000 feet. Its lowest point is at Indian divide, which has an elevation of 6,952 feet and is crossed by the Carrizozo-Capitan branch of the El Paso and Northeastern Railway. The surface is rough. The grazing value is very low, owing to overstocking. The drainage is westward by Nogal Arroyo and its tributaries and eastward by Indian Canyon, both of which are intermittent streams of little consequence.

Stand of trees in T. 8 S., R. 13 E.

	Cords.	Feet B. M.
Yellow pine		510,000
Piñon	24,000	.....
Juniper	4,000	.....
Cedar	12,000	.....
Total	40,000	510,000

Conditions of timber trees in T. 8 S., R. 13 E.

Average total height	feet	40
Average height, clear	do	12
Average diameter, breast-high	inches	9
Dead	per cent	2
Diseased	do	1
Average age	years	55
Reproduction		Medium.

A. LITTER LEFT AFTER CULLING FOR LOGS.

B. ROOTS OF BLACK WALNUT EXPOSED IN CREEK BED.

Township 8 South, Range 14 East.

Twenty-one sections of this township are in the reserve. The area covers a low divide in the Capitan Mountains, and its principal drainage is by Gyp Springs Canyon, a tributary of Salado Creek. At Jacobs ranch, in sec. 1, is an abundance of spring water for local use and for the irrigation of a small orchard. There is also good drinking water in sec. 18. The entire township has been grazed—the southern portion, which is outside the reserve, to an injurious extent. The large percentage of dead trees is attributed by the settlers to the continued droughts.

Stand of trees in T. 8 S., R. 14 E.

	Cords.	Feet B. M.
Yellow pine		840,000
Piñon	39,600	.....
Juniper	19,800	.....
Cedar	6,600	.....
Total	66,000	840,000

Conditions of timber trees in T. 8 S., R. 14 E.

Average total height	feet..	50
Average height, clear	do....	12
Average diameter, breast-high	inches..	10
Dead (95 per cent Piñon)	per cent..	10
Diseased	do....	5
Average age	years..	60
Reproduction		Medium.

Township 8 South, Range 15 East.

The southwestern portion of this township is rolling land of easy gradient, but the surface is generally rocky and bowlder strewn. The rest of the township is traversed by the rounded summits of the Capitan Mountains, which are cut by Capitan Pass. The township is comparatively inaccessible for stock, and therefore has not been badly overgrazed.

Settlers in the southern part haul water from sec. 35, to which point it has been conveyed by troughs a distance of 2 miles, from the foot of the Capitan Mountains. Several attempts have been made to get water by sinking wells, and on sec. 31, at a depth of 100 feet, a supply was obtained, which subsequently failed.

There has been considerable culling for railroad ties in the northwest portion of this township, and in secs. 35 and 36 several years ago there was culling for fuel for the supply of Fort Stanton. The forests are mixed, and the estimated stand is the heaviest in the reserve.

Stand of trees in T. 8 S., R. 15 E.

	Cords.	Feet B. M.
Yellow pine		32,917,000
Red fir		11,970,000
White fir		2,993,000
Mexican white pine		11,970,000
Piñon	23,400	.....
Juniper	11,700	.....
Cedar	3,900	.....
Total	39,000	59,850,000

Conditions of timber trees in T. 8 S., R. 15 E.

Average total height	feet..	50
Average height, clear	do...	14
Average diameter, breast-high	inches..	12
Dead, woodland	per cent..	10
Dead, timber trees	do...	1
Diseased	do...	1
Average age	years..	80
Reproduction		Good.

Township 8 South, Range 16 East.

This township is mountainous and rugged. The sharp backbone of the Capitan Mountains divides it into equal parts, which drain north into Carrizo Creek through numerous small canyons and south into Salado Creek. The mountains of this range reach their highest elevation, over 10,000 feet, in sec. 15. At the higher elevations, mainly on the north slope, are numerous small springs, and in sec. 34 is a spring which is being used in secs. 3 and 10, T. 9 S., R. 16 E., and supplies sufficient water for 200 head of cattle and for two ranchers. The grazing value of this township is good. About fifteen years ago several small portable sawmills operated on the north slope and culled from the principal canyons.

Stand of trees in T. 8 S., R. 16 E.

	Cords.	Feet B. M.
Yellow pine		34,252,000
Red fir		11,417,000
White fir		2,854,000
Engelmann spruce		5,709,000
Mexican white pine		2,854,000
Piñon	5,400	.....
Juniper	6,750	.....
Cedar	1,350	.....
Total	13,500	57,086,000

Conditions of timber trees in T. 8 S., R. 16 E.

Average total height	feet..	40
Average height, clear	do...	8
Average diameter, breast-high	inches..	8
Dead	per cent..	10
Diseased	do...	3
Average age	years..	60
Reproduction		Very good.

Township 8 South, Range 17 East.

This township includes the eastern portion of the Capitan Mountains and is exceedingly rough and broken. It has not been overgrazed by cattle, because of its comparative inaccessibility. At higher elevations in all canyons there is running water in small quantities. In the northern portion there has been some culling of the woodland for fuel.

Stand of trees in T. 8 S., R. 17 E.

	Cords.	Feet B. M.
Yellow pine		18,060,000
Red fir		7,525,000
White fir		1,505,000
Engelmann spruce		1,505,000
Mexican white pine		1,505,000
Piñon	6,000	.....
Juniper	9,000	.....
Cedar	9,000	.....
Oak	6,000	.....
Total	30,000	30,100,000

Conditions of timber trees in T. 8 S., R. 17 E.

Average total height	feet..	40
Average height, clear	do....	10
Average diameter, breast-high	inches..	9
Dead	per cent..	10
Diseased	do....	3
Average age	years..	55
Reproduction		Very good.

Township 8 South, Range 18 East.

The surface along the western boundary is very rugged and precipitous, marking the abrupt termination of the Capitan Mountains. In the central portions the gradient is very gentle, while in the eastern areas are limestone hills, cut by small canyons to a depth of about 150 feet. The drainage is eastward by Cedar Canyon and its numerous smaller tributaries, all of which are intermittent.

There are numerous wells and springs on settled lands. There has been considerable culling all over the woodland; in fact, the majority of the settlers have for years earned their livelihood by hauling cordwood to Roswell, a distance of 50 miles, where there is an increasing market for fuel and fencing. The grazing value is low, owing to overstocking.

Stand of trees in T. 8 S., R. 18 E.

	Cords.	Feet B. M.
Yellow pine		2,465,000
Piñon	19,600	.....
Juniper	14,700	.....
Oak	14,700	.....
Total	49,000	2,465,000

Conditions of timber trees in T. 8 S., R. 18 E.

Average total height	feet..	40
Average height, clear	do....	10
Average diameter, breast-high	inches..	10
Dead	per cent..	3
Diseased	do....	1
Average age	years..	70
Reproduction, woodland		Very good.
Reproduction, yellow pine		Medium.

Township 9 South, Range 10 East.

This township is a gently rolling plain from which rise two of the three hills known as Tres Cerros. These three hills are nearly equidistant, range due north and south, and are a prominent feature of the landscape. The drainage is westward toward the Malpais. At the head of Canyon del Agua is the only perpetual flow of water in the township. The plain is the southern extension of Carrizozo Flats and has been badly overgrazed by both cattle and sheep.

Stand of trees in T. 9 S., R. 10 E.

	Cords.	Feet B. M.
Yellow pine		200,000
Piñon	1,050	.....
Cedar	450	.....
Total	1,500	200,000

Conditions of timber trees in T. 9 S., R. 10 E.

Average total height	feet..	35
Average height, clear	do....	10
Average diameter, breast-high	inches..	8
Dead	per cent..	1
Average age	years..	60
Reproduction		Medium.

A. EASTERN END OF CAPITAN MOUNTAINS.

B. ENGELMANN SPRUCE AND MEXICAN WHITE PINE.

Township 9 South, Range 11 East.

This township covers in part the northern end of the Sierra Blanca and has a very rough and broken surface. At the higher elevations are several small perpetual streams, which become intermittent before reaching the adjoining plains. The grazing value is good. There has been some culling for saw logs in Nogal Canyon, near the eastern boundary.

Stand of trees in T. 9 S., R. 11 E.

	Cords.	Feet B. M.
Yellow pine		4,720,000
Red fir		1,180,000
Piñon	7,250	.....
Juniper	4,350	.....
Cedar	2,900	.....
Total	14,500	5,900,000

Conditions of timber trees in T. 9 S., R. 11 E.

Average total height	feet..	60
Average height, clear	do....	12
Average diameter, breast-high	inches..	12
Dead	per cent..	2
Diseased	do....	1
Average age	years..	70
Reproduction		Good.

Township 9 South, Range 12 East.

This irregular township is unsurveyed, but is assumed to be of about the same area as the irregular townships on the north and south. It covers in part the foothills of the Sierra Blanca and drains easterly into Nogal Canyon. The southern portion supports neither woodland nor forest, but is good grazing land.

Stand of trees in T. 9 S., R. 12 E.

	Cords.	Feet B. M.
Yellow pine		432,000
Red fir		48,000
Piñon	2,700	.....
Juniper	1,350	.....
Cedar	450	.....
Total	4,500	480,000

Conditions of timber trees in T. 9 S., R. 12 E.

Average total height	feet..	50
Average height, clear	do....	12
Average diameter, breast-high	inches..	10
Average age	years..	60
Reproduction		Good.

Township 9 South, Range 13 East.

The surface of this township, while not strictly a mesa, generally goes by that name. It is rolling, with an easy gradient toward the east, and is cut by numerous arroyos, which drain into Salado Creek or Nogal Canyon. A plentiful supply of good well water has been obtained in the southern portions.

Stand of trees in T. 9 S., R. 13 E.

	Cords.	Feet B. M.
Yellow pine		160,000
Piñon	21,250	.....
Juniper	12,750	.....
Cedar	8,500	.....
Total	42,500	160,000

Conditions of timber trees in T. 9 S., R. 13 E.

Average total height	feet..	40
Average height, clear	do..	12
Average diameter, breast-high	inches..	8
Dead	per cent..	1
Average age	years..	50
Reproduction		Poor.

Township 9 South, Range 17 East.

This township has not a very steep gradient, as it includes the long spurs from the Capitan Mountains. The surface is generally rocky and bowlder strewn. The drainage is by numerous arroyos, which are tributary to Bluewater Canyon. The township is being grazed, principally by goats. There has been some culling in the woodland of secs. 8, 13, 17, 20, 28, 29, and 33 for fuel and fencing.

Stand of trees in T. 9 S., R. 17 E.

	Cords.	Feet B. M.
Yellow pine		3,480,000
Piñon	7,200	.....
Juniper	14,400	.....
Cedar	10,800	.....
Oak	1,800	.....
Other species	1,800	.....
Total	36,000	3,480,000

Conditions of timber trees in T. 9 S., R. 17 E.

Average total height	feet..	35
Average height, clear	do....	10
Average diameter, breast-high	inches..	10
Average age	years..	65
Reproduction		Good.

Township 9 South, Range 18 East.

The surface is mainly a series of limestone hills cut by dry canyons, which in the eastern part are 100 to 200 feet deep. The drainage is eastward by Bluewater Canyon and its numerous tributaries, all of which are intermittent. An abundance of good water has been found at a depth of 4 feet in sec. 16. The grazing value is low, owing to overstocking. All of the western portion has been culled for fuel and fencing, which was marketed at Roswell.

Stand of trees in T. 9 S., R. 18 E.

	Cords.
Juniper	13,500
Cedar	2,700
Oak	8,100
Other species	2,700
Total	27,000

Township 10 South, Range 9 East.

The surface is broken by a long and partly detached spur from the Sierra Blanca, the highest point being 7,000 feet elevation, or nearly 2,000 feet above the surrounding plain. The western and southeastern portions are nearly level. The entire township has been badly overgrazed by cattle and sheep, and at the present time has a very low grazing value. There is no timber, and the only woodland is a small area in the northeastern portion.

Stand of trees in T. 10 S., R. 9 E.

	Cords.
Piñon	250
Cedar	250
Total	500

Township 10 South, Range 10 East.

The southwestern portion of this township is a nearly level drainage basin of one of the branches of Three Rivers. The rest is rough, being broken by spurs and foothills from the Sierra Blanca. The flow of Three Rivers is perpetual for about 2½ miles in this township. The grazing value is low, owing to overgrazing by cattle and sheep.

Stand of trees in T. 10 S., R. 10 E.

	Cords.	Feet B. M.
Yellow pine		44,000
Engelmann spruce		396,000
Piñon	3,250	.....
Juniper	650	.....
Cedar	1,300	.....
Oak	1,300	.....
Total	6,500	440,000

Conditions of timber trees in T. 10 S., R. 10 E.

Average total height	feet..	40
Average height, clear (yellow pine)	do....	14
Average diameter, breast-high	inches..	10
Average age	years..	70
Reproduction		Poor.

Township 10 South, Range 11 East.

This township has a very high relief, as it includes the northern summits of the Sierra Blanca, the highest mountains in this portion of New Mexico. Although it does not support as great a stand of timber as other townships in the reserve, in respect of drainage it is perhaps the most important. All the streams are perpetual within the township, and two—Rio Bonito and Rio Ruidoso—are perpetual throughout their length and are important for irrigation. The grazing value is high, as the area has never been overstocked.

Above 9,000 feet the Engelmann spruce is gradually dying out. There have been several burns on the eastern slopes, and the litter which has resulted is now a menace to the standing forest. For the foregoing reasons this township deserves a more careful patrol than any other within this reserve.

Stand of trees in T. 10 S., R. 11 E.

	Cords.	Feet B. M.
Yellow pine		10,194,000
Red fir		4,078,000
White fir		8,155,000
Engelmann spruce		14,271,000
Mexican white pine		4,077,000
Piñon	80	.....
Juniper	80	.....
Total	160	40,775,000

Conditions of timber trees in T. 10 S., R. 11 E.

Average total height	feet..	40
Average height, clear	do....	11
Average diameter, breast-high	inches..	10
Dead (principally spruce)	per cent..	20
Average age	years..	70
Reproduction		Medium.

Township 10 South, Range 12 East.

This is an irregular, partly surveyed township containing less than seven sections. It covers a portion of the steep and broken slopes of the Sierra Blanca and is drained by the Rio Bonito and Eagle Creek. It has all been grazed, but not

A. SAWMILL AND CULLED TIMBER.

B. CULTIVATED VALLEY IN THE WOODLAND AREA.

overstocked. Eight years ago there was some culling of logs for lumber in sec. 1 along Kraut Gulch, a tributary of the Rio Bonito.

Stand of trees in T. 10 S., R. 12 E.

	Feet B. M.
Yellow pine	2,232,000
Red fir	1,116,000
White fir	1,116,000
Mexican white pine	1,116,000
Total	5,580,000

Conditions of timber trees in T. 10 S., R. 12 E.

Average total height	feet	45
Average height, clear	do	10
Average diameter, breast-high	inches	10
Dead	per cent	2
Average age	years	70
Reproduction		Good.

Township 10 South, Range 13 East.

The surface of the western part is bold, consisting of spurs from the Sierra Blanca, flattening in the eastern part into a general mesa-like surface, which is cut by three streams and their tributaries. The drainage is by the Rio Bonito, a perpetual stream, and by Little and Eagle creeks, which are intermittent, all draining eastward. About ten years ago some portable sawmills operated in all the principal canyons, and the methods of logging were wasteful. A sawmill of small capacity is now located in sec. 31 and supplies the local demand. The grazing value is good in the western portions of this township, but the central and eastern portions have been badly overstocked.

Stand of trees in T. 10 S., R. 13 E.

	Cords.	Feet B. M.
Yellow pine		14,895,000
Red fir		827,000
White fir		828,000
Piñon	15,300	.....
Juniper	13,600	.....
Cedar	3,400	.....
Oak	1,700	.....
Total	34,000	16,550,000

Condition of timber trees in T. 10 S., R. 13 E.

Average total height	feet	50
Average height, clear	do	10
Average diameter, breast-high	inches	10
Dead	per cent	5
Diseased	do	1
Average age	years	65
Reproduction		Good.

Township 10 South, Range 14 East.

The eastern portion of this township is cut by two canyons 150 feet deep, through which flow Little and Eagle creeks, but in the central and western portions are extensive mesas, which are covered with a luxuriant growth of black gramma grass. The drainage is by Little and Eagle creeks, which are intermittent, and by the Rio Bonito, which is perpetual. The entire township has been overstocked for years, and the grazing value is low. The denudation of the surface has permitted the cutting of numerous water runs and gullies.

Stand of trees in T. 10 S., R. 14 E.

	Cords.	Feet B. M.
Yellow pine		180,000
Piñon	15,400	.....
Juniper	17,325	.....
Cedar	5,775	.....
Total	38,500	180,000

Conditions of timber trees in T. 10 S., R. 14 E.

Average total height	feet	45
Average height, clear	do	10
Average diameter, breast-high	inches	9
Dead	per cent	3
Diseased	do	1
Average age	years	55
Reproduction		Medium.

Township 10 South, Range 15 East.

The greater portion of the surface is composed of limestone hills which are cut by canyons over 100 feet deep. The drainage is by the Rio Ruidoso, a perpetual stream, and by Little and Eagle creeks, which are intermittent. Springs and wells in secs. 9 and 34 furnish an abundance of water for domestic purposes and for the herds of goats which are raised in this vicinity. The northern portion of this township is being rapidly culled for fuel, which is marketed at the marine hospital at Fort Stanton. It was the former custom to remove only the dead

wood, but much of the living woodland was included in the recent cuttings. The grazing value is low, owing partly to the rock-strewn, eroded surface and partly to overstocking.

Stand of trees in T. 10 S., R. 15 E.

	Cords.	Feet B. M.
Yellow pine		85,000
Red fir		4,000
Piñon	36,300	.....
Juniper	18,150	.....
Cedar	6,050	.....
Total	60,500	89,000

Conditions of timber trees in T. 10 S., R 15 E.

Average total height	feet	45
Average height, clear	do	10
Average diameter, breast-high	inches	8
Dead	per cent	2
Average age	years	50
Reproduction		Poor.

Township 11 South, Range 9½ East.

This irregular township includes a portion of the valley of Three Rivers, which is bordered on the north by high, rocky escarpments known as the "Palisades" and on the south by rolling and mesa lands. About 3,000 acres of bottoms along the "river" bed are arable, of which 11 per cent is in cultivation, the rest being covered in part with groves of walnut, box elder, and ash. According to testimony the stream was formerly perpetual, but is now intermittent in and west of this township. The whole township has been overgrazed, and its value now is low. There has been some slight culling for fuel among the deciduous trees.

Stand of trees in T. 11 S., R. 9½ E.

	Cords.
Oak	150
Walnut	1,500
Box elder	1,300
Ash	50
Total	3,000

Township 11 South, Range 10 East.

The eastern portion is mountainous, changing gradually westward into rolling and mesa lands. A branch of Three Rivers crosses the northern portion and is perpetual for the greater part of its length. Other valleys and arroyos

have intermittent flows. The grazing value is medium, but the western part has been sheeped.

Stand of trees in T. 11 S., R. 10 E.

	Cords.	Feet B. M.
Yellow pine		3,458,000
Red fir		1,482,000
Piñon	1,400	.....
Juniper	350	.....
Cedar	350	.....
Walnut	700	.....
Box elder	630	.....
Oak	70	.....
Total	3,500	4,940,000

Conditions of timber trees in T. 11 S., R. 10 E.

Average total height	feet	45
Average height, clear	do	8
Average diameter, breast-high	inches	10
Dead	per cent	1
Average age	years	65
Reproduction		Good.

Township 11 South, Range 11 East.

The following description and estimates include a strip of land which, when surveyed, may be known as T. 11 S., R. 12 E. The entire area is at present within the Mescalero Apache Indian Reservation. It includes the highest area in southeastern New Mexico, and at Sierra Blanca reaches an elevation of 11,882 feet. It is the highest point on the divide between the Rio Pecos and the basin of the Malpais, and from it radiate several small but important streams. It includes, together with the township bordering it on the north, the most important watershed of the region. It has all been sheeped, but fortunately not to great excess, and its grazing value is still good.

Stand of trees in T. 11 S., R. 11 E.

	Cords.	Feet B. M.
Yellow pine		4,764,000
Red fir		3,573,000
White fir		7,146,000
Engelmann spruce		7,146,000
Mexican white pine		1,191,000
Piñon	700	.....
Oak	3,500	.....
Other species	2,800	.....
Total	7,000	23,820,000

A. BLACK WALNUT NEAR THREE RIVERS.

B. TYPICAL PIÑON IN VERY SCATTERED WOODLAND.

Conditions of timber trees in T. 11 S., R. 11 E.

Average total height	feet	45
Average height, clear	do	7
Average diameter, breast-high	inches	8
Dead	per cent	5
Diseased	do	1
Average age	years	60
Reproduction		Good.

Township 11 South, Range 13 East.

The western third of this township covers steep slopes of the Sierra Blanca. The rest has an easy gradient toward the southeast and is drained by the Rio Ruidoso, a perpetual stream. A water-power sawmill of small capacity was operated in sec. 26 about sixteen years ago, but most of the logging for its supply was done on the Mescalero Apache Indian Reservation. The western portion of this township is a favorite resort for campers and health seekers. The grazing value is good.

Stand of trees in T. 11 S., R. 13 E.

	Cords.	Feet B. M.
Yellow pine		32,371,000
Red fir		1,704,000
Piñon	10,200	.....
Juniper	3,400	.....
Cedar	3,400	.....
Total	17,000	34,075,000

Conditions of timber trees in T. 11 S., R. 13 E.

Average total height	feet	50
Average height, clear	do	12
Average diameter, breast-high	inches	10
Dead, principally woodland	per cent	3
Diseased	do	1
Average age	years	65
Reproduction		Very good.

Township 11 South, Range 14 East.

The surface is high, rolling, rather bold, and bounded on the south by high mesas which are cut by numerous small arroyos and some unimportant canyons. The drainage is mainly into the Rio Ruidoso. There has been a small amount of culling in the woodland for the domestic use of settlers. The grazing value is medium. At present the range is being used for cattle and goats; in the past it has been badly overstocked.

Stand of trees in T. 11 S., R. 14 E.

	Cords.	Feet B. M.
Yellow pine		8,092,000
Red fir		449,000
White fir		449,000
Piñon	52,800	.....
Juniper	26,400	.....
Cedar	8,800	.....
Total	88,000	8,990,000

Conditions of timber trees in T. 11 S., R. 14 E.

Average total height	feet..	50
Average height, clear	do....	11
Average diameter, breast-high	inches..	10
Dead	per cent..	3
Diseased	do....	1
Average age	years..	70
Reproduction		Very good.

Township 11 South, Range 15 East.

The surface is interrupted by limestone hills, which in the northern portion of the township are badly cut by dry canyons from 100 to 200 feet deep. Toward the head of the canyons in the southern portion the surface has a more easy gradient. The drainage is northward into the Rio Ruidoso by numerous dry canyons. The grazing value is good, as the land has not been badly overstocked, owing, perhaps, to the lack of water.

Stand of trees in T. 11 S., R. 15 E.

	Cords.	Feet B. M.
Yellow pine		6,042,000
Red fir		318,000
Piñon	48,600	.....
Juniper	16,200	.....
Cedar	16,200	.....
Total	81,000	6,360,000

Conditions of timber trees in T. 11 S., R. 15 E.

Average total height	feet..	50
Average height, clear	do....	12
Average diameter, breast-high	inches..	10
Dead	per cent..	3
Diseased	do....	2
Average age	years..	70
Reproduction		Medium.

Township 12 South, Range 10 East.

The east half is rough and mountainous; the west half slopes gently toward the Malpais. There are no perpetual streams, and only one well, in sec. 8, which is used as a watering station for cattle. The supply is small and of inferior quality. The land has been grazed by both cattle and sheep. There is no timber, and the woodland is a very scattering growth in the southeastern part of the township.

Stand of trees in T. 12 S., R. 10 E.

	Cords.
Piñon	1,200
Cedar	800
Total	2,000

Township 12 South, Range 11 East.

The western portion includes, in part, one of the high spurs of the Sierra Blanca. The eastern portion lies in the nearly level basin of the Rinconada, an intermittent stream which flows westerly toward the Malpais. The stream flows in sec. 35, but the water is of very poor quality. The overgrazing by sheep and cattle has contributed to the loosening of the top soil, which the freshets are eroding rapidly. There has been some culling for fuel.

Stand of trees in T. 12 S., R. 11 E.

	Cords.	Feet B. M.
Yellow pine		2,772,000
Red fir		308,000
Piñon	8,750	.....
Juniper	5,250	.....
Cedar	3,500	.....
Total	17,500	3,080,000

Conditions of timber trees in T. 12 S., R. 11 E.

Average total height	feet	35
Average height, clear	do	8
Average diameter, breast-high	inches	7
Dead	per cent	3
Diseased	do	1
Reproduction		Poor.

Township 12 South, Range 12 East.

The southern termination of the Sierra Blanca runs into this township and makes the topography very rough and rocky. The higher elevations are timberless, and the streams are all intermittent. There has been slight culling of fuel for domestic use, and several years ago there was some culling of yellow-pine

logs for a sawmill located in T. 11 S., R. 13 E. It is all good grazing land, and its value for this purpose is high, as the greater portion has not been badly overstocked.

Stand of trees in T. 12 S., R. 12 E.

	Cords.	Feet B. M.
Yellow pine		9,058,000
Red fir		1,294,000
White fir		2,588,000
Piñon	13,650	.....
Juniper	9,100	.....
Cedar	4,550	.....
Oak	18,200	.....
Total	45,500	12,940,000

Conditions of timber trees in T. 12 S., R. 12 E.

Average total height	feet	50
Average height, clear	do	11
Average diameter, breast-high	inches	12
Dead	per cent	2
Diseased	do	1
Average age	years	75
Reproduction		Very poor.

Township 13 South, Range 10 East.

Except along the west boundary, this township has a very broken surface. It has been ruined by overgrazing. There is a well and windmill in sec. 2, and in sec. 32 is a perpetual spring, but the water in both is very poor. There is no timber, and only a very scattering growth of woodland on the eastern portion.

Stand of trees in T. 13 S., R. 10 E.

	Cords.
Piñon	1,800
Cedar	1,200
Total	3,000

Township 13 South, Range 11 East.

This township comprises broken hills of limestone and gypsum, cut by the narrow valleys of the Rio Tularosa and Arroyo Rinconada, the latter an intermittent stream. The surface is rough. The township has all been sheeped, and its grazing value is only medium. There has been some culling of fuel in the woodland.

Stand of trees in T. 13 S., R. 11 E.

	Cords.
Piñon	24,700
Cedar	13,300
Total	38,000

A. VETERAN MEXICAN WHITE PINE.

B. YELLOW-PINE LITTER AFTER CUTTING RAILROAD TIES.

SUMMARY.

Percentages of timber-tree species in and adjacent to Lincoln Forest Reserve, New Mexico.

Township.	Range.	Yellow pine.	Red fir.	White fir.	Engelmann spruce.	Mexican white pine.
7 south	11 east					
7 south	12 east	30	70			
7 south	13 east	90	10			
7 south	14 east	100				
7 south	15 east	100				
7 south	16 east	100				
7 south	17 east	100				
8 south	11 east					
8 south	12 east					
8 south	13 east	100				
8 south	14 east	100				
8 south	15 east	55	20	5		20
8 south	16 east	60	20	5	10	5
8 south	17 east	60	25	5	5	5
8 south	18 east	100				
9 south	10 east	100				
9 south	11 east	80	20			
9 south	12 east	90	10			
9 south	13 east	100				
9 south	17 east	100				
9 south	18 east					
10 south	9 east					
10 south	10 east	10			90	
10 south	11 east	25	10	20	35	10
10 south	12 east	40	20	20		20
10 south	13 east	90	5	5		
10 south	14 east	100				
10 south	15 east	95	5			
11 south	9½ east					
11 south	10 east	70	30			
11 south	11 east	20	15	30	30	5
11 south	13 east	95	5			
11 south	14 east	90	5	5		
11 south	15 east	95	5			
12 south	10 east					
12 south	11 east	90	10			
12 south	12 east	70	10	20		
13 south	10 east					
13 south	11 east					

Stand and classification of timber in and adjacent to Lincoln Forest Reserve, New Mexico.

Township.	Range.	Total stand.	Average stand per acre.	Yellow pine.	Red fir.	White fir.	Engelmann spruce.	Mexican white pine.
		M feet B. M.	*Feet B. M.*	*M feet B. M.*	*M feet B. M.*	*M feet B. M.*	*M feet B. M.*	*M feet B. M.*
7 south	11 east							
7 south	12 east	2,145	1,500	643	1,502			
7 south	13 east	10,900	1,222	9,810	1,090			
7 south	14 east	560	1,166	560				
7 south	15 east	2,540	1,984	2,540				
7 south	16 east	1,120	1,400	1,120				
7 south	17 east	180	500	180				
8 south	11 east							
8 south	12 east							
8 south	13 east	510	500	510				
8 south	14 east	840	953	840				
8 south	15 east	59,850	4,661	32,917	11,970	2,993		11,970
8 south	16 east	57,086	2,623	34,252	11,417	2,854	5,709	2,854
8 south	17 east	30,100	1,563	18,060	7,525	1,505	1,505	1,505
8 south	18 east	2,465	1,185	2,465				
9 south	10 east	200	500	200				
9 south	11 east	5,900	1,046	4,720	1,180			
9 south	12 east	480	1,500	432	48			
9 south	13 east	160	500	160				
9 south	17 east	3,480	853	3,480				
9 south	18 east							
10 south	9 east							
10 south	10 east	440	500	44			396	
10 south	11 east	40,775	2,347	10,194	4,078	8,155	14,271	4,077
10 south	12 east	5,580	1,516	2,232	1,116	1,116		1,116
10 south	13 east	16,550	1,151	14,895	827	828		
10 south	14 east	180	500	180				
10 south	15 east	89	500	85	4			
11 south	9½ east							
11 south	10 east	4,940	1,357	3,458	1,482			
11 south	11 east	23,820	2,282	4,764	3,573	7,146	7,146	1,191
11 south	13 east	34,075	1,642	32,371	1,704			
11 south	14 east	8,900	1,208	8,092	449	449		
11 south	15 east	6,360	1,169	6,042	318			
12 south	10 east							
12 south	11 east	3,080	770	2,772	308			
12 south	12 east	12,940	2,432	9,058	1,294	2,588		
13 south	10 east							
13 south	11 east							
Total		336,335	1,913	207,076	49,885	27,634	29,027	22,713

Classification of lands in and adjacent to Lincoln Forest Reserve, New Mexico.

Township.	Range.	Total area.	Timbered area.	Wooded area.	Burned area.	Naturally timberless area.	Cultivated area.
		Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
7 south	11 east [a]	23,046.34	.....	4,140	.....	18,906.34	.....
7 south	12 east	3,324.84	1,430	1,894.84	.....	.....	.....
7 south	13 east [b]	15,431	8,920	6,511	.....	.....	100
7 south	14 east	23,149.92	480	10,040	.....	12,629.92	60
7 south	15 east	22,984.93	1,280	6,360	.....	15,344.93	25
7 south	16 east [b]	15,357	800	11,440	.....	3,117	80
7 south	17 east [b]	15,450	360	13,850	.....	1,240	100
8 south	11 east [a]	22,010.71	.....	1,300	.....	20,710.71	.....
8 south	12 east	4,166.24	.....	400	.....	3,766.24	.....
8 south	13 east [c]	23,079.68	1,020	19,379.68	.....	2,680	80
8 south	14 east [b]	13,461	880	12,581	.....	.....	90
8 south	15 east	22,893.37	12,840	10,053.37	.....	.....	40
8 south	16 east	23,044.50	21,760	1,284.50	.....	.....	.....
8 south	17 east	23,147.38	19,260	3,887.38	.....	.....	20
8 south	18 east [d]	23,145.63	2,080	21,065.63	.....	.....	80
9 south	10 east	23,041.66	400	1,520	.....	21,121.66	.....
9 south	11 east	22,010.71	5,640	10,100	.....	6,270.71	60
9 south	12 east	4,166.24	320	2,060	.....	1,786.24	40
9 south	13 east [d]	22,436.14	320	16,616	.....	5,500.14	369
9 south	17 east	21,982.78	4,080	17,902.78	.....	.....	30
9 south	18 east [d]	23,171.46	.....	9,691	.....	13,480.46	80
10 south	9 east	23,011.37	.....	440	.....	22,571.37	.....
10 south	10 east	23,036.58	880	6,720	.....	15,436.58	182
10 south	11 east	22,010.71	17,370	160	920	3,560.71	120
10 south	12 east	4,166.24	3,680	.....	.....	486.24	30
10 south	13 east [c]	22,802.54	14,380	5,470	.....	2,952.54	282
10 south	14 east [d]	22,824	360	12,520	.....	9,944	230
10 south	15 east [d]	23,017.07	179	22,120.07	.....	718	1,000
11 south	9½ east	15,323.76	.....	520	.....	14,803.76	330
11 south	10 east [c]	23,080.72	3,640	7,100	.....	12,340.72	100
11 south	11 east [d]	27,200	10,440	1,680	560	14,520	.....
11 south	13 east [c]	23,058.45	20,750	2,308.45	.....	.....	84
11 south	14 east [d]	23,049.36	7,443	15,606.36	.....	.....	400
11 south	15 east [d]	22,887.57	5,440	17,447.57	.....	.....	40
12 south	10 east	21,631.23	.....	7,000	.....	14,631.23	.....
12 south	11 east [d]	21,600	4,000	17,600	.....	.....	.....
12 south	12 east [d]	21,000	5,320	13,520	.....	2,160	45
13 south	10 east	23,540.79	.....	11,420	.....	12,120.79	.....
13 south	11 east	21,886.82	.....	21,886.82	.....	.....	100
Total		775,628.74	175,752	345,596.45	1,480	252,800.29	4,197

[a] Part of these townships proposed to be eliminated.
[b] A portion only of this township in the reserve.
[c] Portion in the reserve, balance in proposed addition.
[d] Proposed additions to the reserve.

Estimated cords of fuel in and adjacent to Lincoln Forest Reserve, New Mexico.

Township.	Range.	Total.	Pifion.	Juniper.	Cedar.	Oak.	Other species.
		Cords.	*Cords.*	*Cords.*	*Cords.*	*Cords.*	*Cords.*
7 south	11 east	8,000	4,000	1,600	1,600	800	.....
7 south	12 east	3,800	2,280	1,140	380	.....	.....
7 south	13 east	12,000	5,400	4,200	1,800	600	.....
7 south	14 east	30,000	18,000	9,000	1,500	1,500	.....
7 south	15 east	43,000	19,350	21,500	.....	2,150	.....
7 south	16 east	64,000	28,800	28,800	.....	6,400	.....
7 south	17 east	55,000	27,500	16,500	2,750	8,250	.....
8 south	11 east	1,000	500	.....	500	.....	.....
8 south	12 east	500	250	.....	250	.....	.....
8 south	13 east	40,000	24,000	4,000	12,000	.....	.....
8 south	14 east	66,000	39,600	19,800	6,600	.....	.....
8 south	15 east	39,000	23,400	11,700	3,900	.....	.....
8 south	16 east	13,500	5,400	6,750	1,350	.....	.....
8 south	17 east	30,000	6,000	9,000	9,000	6,000	.....
8 south	18 east	49,000	19,600	14,700	.....	14,700	.....
9 south	10 east	1,500	1,050	.....	450	.....	.....
9 south	11 east	14,500	7,250	4,350	2,900	.....	.....
9 south	12 east	4,500	2,700	1,350	450	.....	.....
9 south	13 east	42,500	21,250	12,750	8,500	.....	.....
9 south	17 east	36,000	7,200	14,400	10,800	1,800	1,800
9 south	18 east	27,000	.....	13,500	2,700	8,100	2,700
10 south	9 east	500	250	.....	250	.....	.....
10 south	10 east	6,500	3,250	650	1,300	1,300	.....
10 south	11 east	160	80	80	.....	.....	.....
10 south	12 east	.....	.....	.....	.....	.....	.....
10 south	13 east	34,000	15,300	13,600	3,400	1,700	.....
10 south	14 east	38,500	15,400	17,325	5,775	.....	.....
10 south	15 east	60,500	36,300	18,150	6,050	.....	.....
11 south	9½ east	3,000	.....	.....	.....	150	2,850
11 south	10 east	3,500	1,400	350	350	.....	1,400
11 south	11 east	7,000	700	.....	.....	3,500	2,800
11 south	13 east	17,000	10,200	3,400	3,400	.....	.....
11 south	14 east	88,000	52,800	26,400	8,800	.....	.....
11 south	15 east	81,000	48,600	16,200	16,200	.....	.....
12 south	10 east	2,000	1,200	.....	800	.....	.....
12 south	11 east	17,500	8,750	5,250	3,500	.....	.....
12 south	12 east	45,500	13,650	9,100	4,550	18,200	.....
13 south	10 east	3,000	1,800	.....	1,200	.....	.....
13 south	11 east	38,000	24,700	.....	13,300	.....	.....
Total	.....	1,026,460	497,910	305,545	136,305	75,150	11,550

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O

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Professional Paper No. 33.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of the United States—folios and separate sheets thereof, (8) Geologic Atlas of the United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports. This paper is the eleventh in series H, the complete list of which follows (all are Professional Papers thus far):

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5. The forests of Washington, a revision of estimates, by Henry Gannett. 1902. 38 pp., 1 pl.

6. Forest conditions in the Cascade Range, Washington, between the Washington and Mount Rainier forest reserves, by F. G. Plummer. 1902. 42 pp., 11 pls.

7. Forest conditions in the Olympic Forest Reserve, Washington, from notes by Arthur Dodwell and T. F. Rixon. 1902. 110 pp., 20 pls.

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Besides the foregoing, three volumes on forestry have been published, as Pt. V of the Nineteenth, Twentieth, and Twenty-first annual reports, each consisting of several papers.

Correspondence should be addressed to—

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

SEPTEMBER, 1904.

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Professional Paper No. 34 Series B, Descriptive Geology, 48

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

THE DELAVAN LOBE OF THE LAKE MICHIGAN GLACIER OF THE WISCONSIN STAGE OF GLACIATION AND ASSOCIATED PHENOMENA

BY

WILLIAM C. ALDEN

WASHINGTON
GOVERNMENT PRINTING OFFICE
1904

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., May 10, 1904.

SIR: I have the honor to transmit herewith the manuscript of a paper entitled "Delavan Lobe of the Lake Michigan Glacier of the Late Wisconsin Stage of Glaciation, and Associated Phenomena," by William C. Alden.

The manuscript has been read and approved by Prof. T. C. Chamberlin, geologist in charge of the section of Pleistocene geology, and I therefore recommend that it be published as a professional paper.

Very respectfully,

C. W. HAYES,
Geologist in Charge of Geology.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

THE DELAVAN LOBE OF THE LAKE MICHIGAN GLACIER OF THE WISCONSIN STAGE OF GLACIATION AND ASSOCIATED PHENOMENA.

By WILLIAM C. ALDEN.

INTRODUCTION.

The purpose of this paper is to throw, if possible, some further light on the relations which existed during the later stages of the Glacial epoch between the glaciers of southeastern Wisconsin, which have been so ably discussed by Dr. T. C. Chamberlin and other writers in various publications, and the glaciers of Illinois, which have received such exhaustive treatment by Mr. Frank Leverett in his recent monograph on the Illinois glacial lobe.

So familiar are the students of Pleistocene geology with the work in the Wisconsin and Illinois fields that it is unnecessary to undertake at this time an exhaustive historical résumé of the results attained, even if the space limitations of this paper would permit. The writer has been engaged during several seasons, under the direction of Dr. T. C. Chamberlin, in investigating the Pleistocene deposits and associated phenomena of southeastern Wisconsin for the United States Geological Survey. The results of this investigation are to be embodied in a series of folios of the Geologic Atlas of the United States. A portion of these results are here presented for the first time. Whatever of value may pertain to these studies is due in very large measure to the intelligent direction, the kindly criticism, and the hearty cooperation of Dr. T. C. Chamberlin, with whom the writer has kept in close touch through personal conference and frequent correspondence during the progress of the work. In the main, the writer is responsible for the field observations, for the final correlation of the details, and for this presentation. For correlations beyond the immediate area studied by the writer, previous publications have been freely drawn upon. There are also a large number of persons who have furnished information or assistance during the progress of the field work to whom the writer wishes to express his obligations.

It may be well to make brief mention concerning the names proposed for the several morainic belts discussed. Heretofore these have been grouped together under the general name "Kettle Range," or "Kettle moraine." The features grouped under one or both of these names have been defined by Prof. T. C. Chamberlin as follows:[a]

"*Kettle Range.*—The term 'Potash Kettle Range' has been popularly used to designate an extensive series of drift hills and ridges in eastern Wisconsin, whose full extent and relationship were unknown previous to the investigations of the present survey, and concerning the true nature and origin of which diverse opinions have been held. As the term 'Potash' has no special significance in this connection, it will be discarded. The northern terminus of the range lies in the town of Casco, Kewaunee County. From this point it stretches away to the southwestward, through the counties of Manitowoc, Sheboygan, Fond du Lac, Waukesha, and into the northern portion of Walworth. At this point it divides, one portion extending southward, through the towns of Richmond and Darien, thence eastward to Lake Geneva, whence the main portion extends northeastward to the vicinity of Burlington, and then southward into Illinois. The other portion, branching from the main range in the town of Whitewater, about 20 miles north of the State line, extends westward to the Rock River, after crossing which it curves to the northward. * * *"

After the definite recognition of two distinct stages of glaciation, a first and a second glacial epoch, the name "Kettle moraine" was given a more extended application, as shown by the following:[b]

"*The Kettle moraine.*—The most striking result of the second glacial advance was the production along the margin of the ice sheet of a great moraine, the most gigantic and remarkable yet known to characterize glacial action. It consists of a great ridged belt of drift disposed in grand loops along what was the glacier's margin. Its reentrant angles penetrated deeply between the adjoining lobes, marking their line of contact. That portion of the moraine which lay between, and was formed by, the joint action of the Green Bay and Lake Michigan glaciers constitutes a succession of irregular hills and ridges, locally known as the 'Kettle Range' from the peculiar depressions which characterize it. As this was the first portion to receive systematic investigation and a specific determination of the true nature and method of its formation, and as this moraine will need a specific name to distinguish it from similar accumulations, the term 'Kettle moraine' may fittingly be applied to it."

Continuing, in a footnote, in the same connection, Professor Chamberlin says:

"It should be remarked in this connection that there are two or more concentric moraines, constituting a belt, rather than a single moraine. These are often forced into contact and confusion, so that their distinct discrimination is impracticable, while at other points they are quite distinct, and separated by several miles distance. It is proposed to apply the name 'Kettle moraine' to the outermost member, when clearly distinguishable, and to extend its use, or that of the term 'Kettle Range,' to the entire group where they are confused so as to be indistinguishable. The Kettle

[a] Geol. Wisconsin, vol. 2, 1877, pp. 205–206.

[b] Geol. Wisconsin, vol. 1, 1882, p. 275.

moraine, therefore, designates the morainic ridge produced by the extreme advance of later glaciation. Names for the inner moraines are not here proposed because, although distinguishable in Wisconsin, as indicated in Volumes II and III, they are displayed in greater distinctness and definition elsewhere, especially in Minnesota and Dakota, from some of the characteristic localities of which it is proper that fitting names should be selected, and such will be announced, if not sooner proposed, in connection with the results of the wider studies of the writer upon the formation now in progress."

Thus far, with the exception of the Lake Border morainic system, these several inner belts have not been definitely correlated with those of neighboring States. In working out the details of the local geological history it is important that many of these features, such as the several moraines of the small lobe under discussion, should be discriminated, but they have not any considerable geographic extent, and hence should be designated by local names, and these have been proposed where it seemed necessary. The same procedure has been followed in the discussion of the several morainic members included by Professor Chamberlin under the name "Kettle moraine" or "Kettle Range." That portion of the general morainic system which lies between and was formed by the joint action of the Green Bay and Lake Michigan glaciers is referred to descriptively in this paper as the "interlobate Kettle moraine," it not being thought desirable at this stage of the investigation to propose a more definite name.

For convenience of reference the following outline of the stages of glaciation and intervals of deglaciation thus far recognized by the United States Geological Survey is here inserted. This outline is modified from that given by Mr. Frank Leverett in his recent monograph on the "Glacial Formations and Drainage Features of the Erie and Ohio Basins,"[a] and is based upon the latest data from the studies of Prof. T. C. Chamberlin, Mr. Frank Leverett, and many other students of glacial phenomena. The principal modification consists in the substitution of the phenomena of the late Wisconsin drift sheets as developed in Wisconsin and Illinois for those represented in the Ohio district.

Outline of drift sheets and intervals.

1. Oldest recognized drift sheet, the sub-Aftonian of Chamberlin, and perhaps the Albertan of Dawson.
2. First interval of deglaciation, Aftonian of Chamberlin.
3. Kansan drift sheet of the Iowa geologists.
4. Second or Yarmouth interval of recession or deglaciation.
5. Illinoian drift sheet.
6. Third or Sangamon interval of recession or deglaciation.
7. Iowan drift sheet and main loess deposit.

[a] Leverett, Frank, The glacial formations and drainage features of the Erie and Ohio basins: Mon. U. S. Geol. Survey, vol. 38, 1899, pp. 21-22.

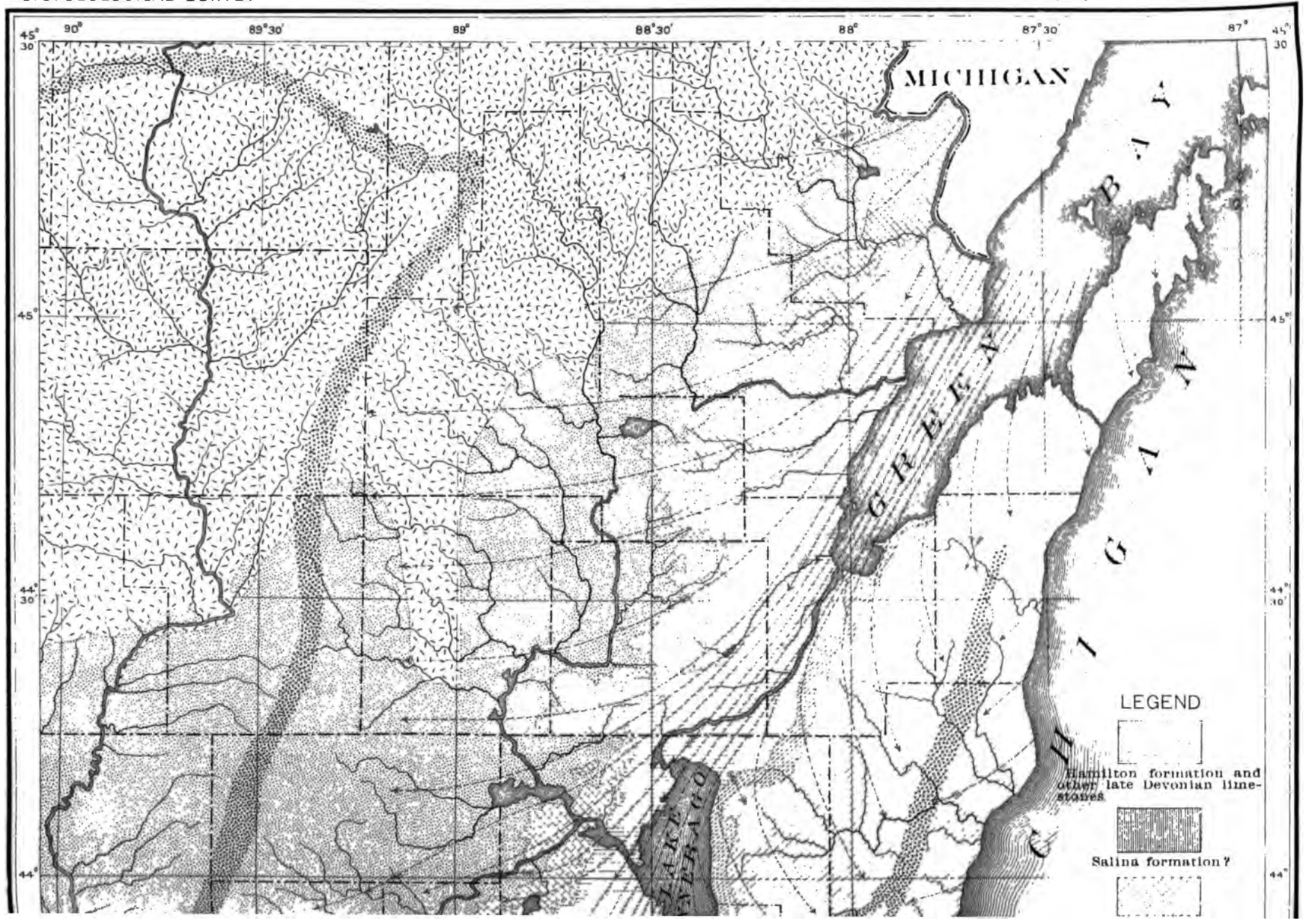
8. Fourth or Peorian interval of recession or deglaciation.
9. Early Wisconsin drift sheets, as represented in Illinois.
   a. Shelbyville morainic system.
   b. Champaign morainic system.
   c. Bloomington morainic system.
   d. Marseilles morainic system.
   (With one of these four morainic systems, possibly the third, is to be correlated the Marengo Ridge of western McHenry County, Ill.)
10. Fifth interval of recession (unnamed), shown by shifting of the ice lobes.
11. Late Wisconsin drift sheet, as represented in Illinois and in southeastern Wisconsin.
   a. Great bowlder belts and accompanying moraines, including, perhaps, the Minooka, Ill., till ridge.
   b. Valparaiso morainic system of the Lake Michigan Glacier. { Genoa, Darien, Elkhorn, and other morainal deposits of the Delavan lobe of the Lake Michigan Glacier. / Johnstown, Milton, Hebron, and certain other morainal deposits of the Green Bay Glacier. }
   c. Lake-border morainic system.
   (No further correlations with the moraines of the Green Bay Glacier have yet been made.)
   d. Lake Chicago submergence, Glenwood stage.
   e. Emergence of plain covered by Lake Chicago.
   f. Partial resubmergence of the plain covered by Lake Chicago, Calumet stage.
   g. Possible second interval of emergence.
   h. Partial resubmergence of the plain covered by Lake Chicago, Toleston stage.
   i. Present stage of Lake Michigan.

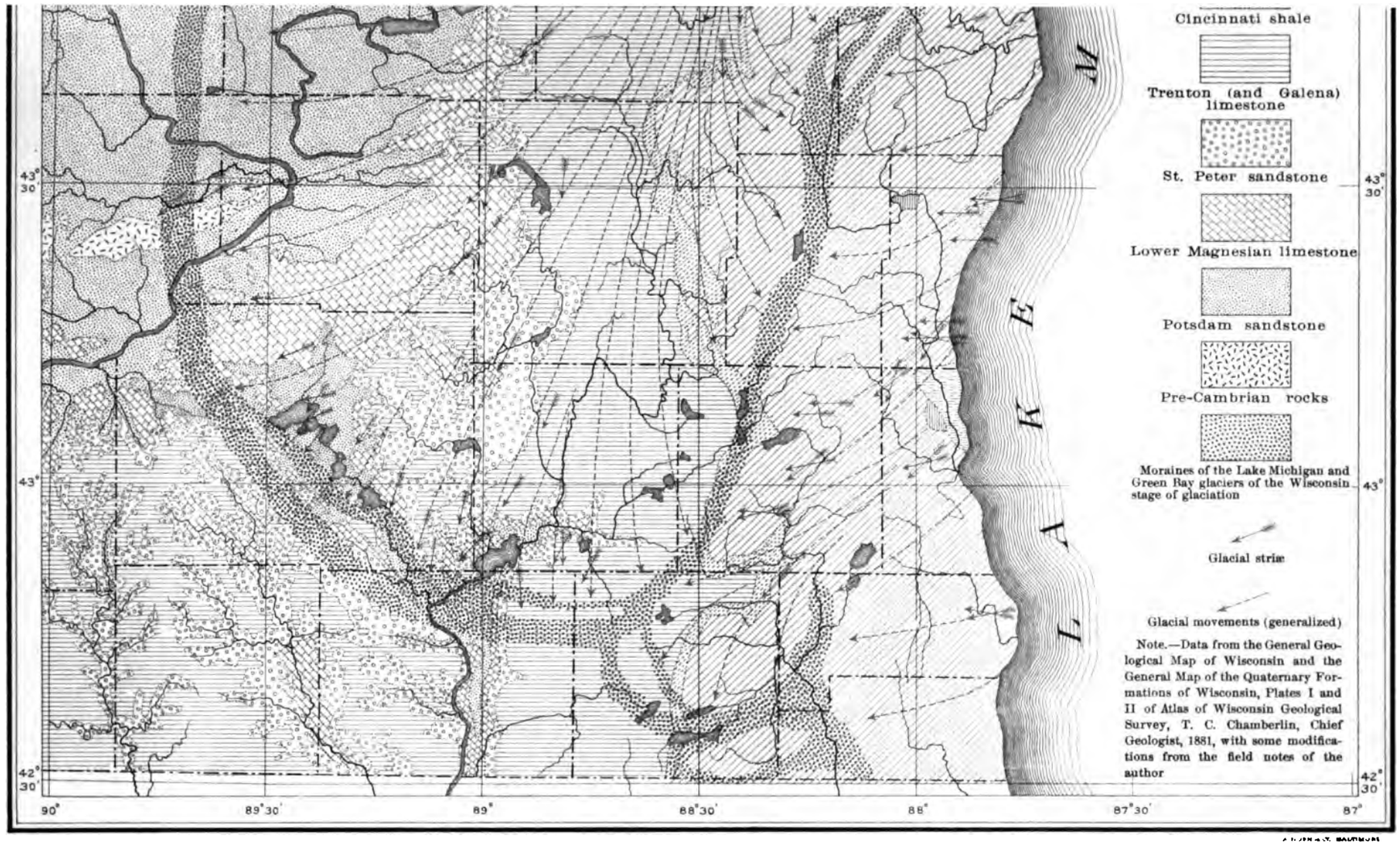
DESCRIPTION OF THE AREA.

GEOGRAPHIC RELATIONS.

The area under discussion lies principally in southeastern Wisconsin, where it embraces Racine, Kenosha, and Walworth counties, and adjacent parts of Milwaukee, Waukesha, Jefferson, Rock, and Dane counties, an area somewhat greater than 2,000 square miles. It includes also a small portion of northeastern Illinois adjacent to the State line. In this area are developed certain glacial phenomena which throw some light on the relations existing between the glaciers of Illinois and Wisconsin during the earlier and later advances of the Wisconsin stage of glaciation. The special feature of this discussion is the Delavan lobe of the Lake Michigan Glacier, which thrust itself out between the converging west front of the Lake Michigan Glacier and the south front of the Green Bay Glacier a distance of 25 miles beyond the main west front of the Lake Michigan Glacier.

On the one hand, this Delavan lobe was an integral part of the Lake Michigan Glacier of the late Wisconsin advance, and, on the other, the relations of its morainal and outwash deposits to those of the Green Bay Glacier appear to


90°
89°30'
89°
88°30'
88°
87°30'
87°
45° 30'
45°
44° 30'
44°
MICHIGAN
GREEN BAY
LAKE MICHIGAN
LEGEND
Hamilton formation and other late Devonian limestones
Salina formation?


Cincinnati shale
Trenton (and Galena) limestone
St. Peter sandstone
Lower Magnesian limestone
Potsdam sandstone
Pre-Cambrian rocks
Moraines of the Lake Michigan and Green Bay glaciers of the Wisconsin stage of glaciation
Glacial striæ
Glacial movements (generalized)
Note.—Data from the General Geological Map of Wisconsin and the General Map of the Quaternary Formations of Wisconsin, Plates I and II of Atlas of Wisconsin Geological Survey, T. C. Chamberlin, Chief Geologist, 1881, with some modifications from the field notes of the author
MICHIGAN
43° 30'
43°
42° 30'
90°
89° 30'
89°
88° 30'
88°
87° 30'
87°

GEOLOGIC MAP OF EASTERN WISCONSIN

SHOWING THE RELATIONS OF THE MOVEMENTS AND DEPOSITS OF THE GLACIERS OF THE WISCONSIN STAGE OF GLACIATION TO THE UNDERLYING FORMATIONS

BY

WILLIAM C. ALDEN

Scale

0 10 20 30 40 50 miles

1903

establish beyond question the contemporaneity of the Lake Michigan and Green Bay glaciers in the occupancy of their outer terminal moraines.

Thus the outer terminal moraine of this Delavan lobe, instead of being the northward continuation of the Marengo Ridge of the early Wisconsin series, as would appear from the statements of some writers, seems to cross the latter ridge near the west end of Lake Geneva in passing eastward to join the Valparaiso terminal morainic system of the main Lake Michigan Glacier in the region south of Burlington, Wis.

GEOLOGICAL STRUCTURE AND PRE-GLACIAL TOPOGRAPHY.

In order to understand the conditions of the development of this Delavan lobe and to fully appreciate the significance of the determinations of the lithological character of the drift, it is necessary to consider briefly the geological structure of the region and the pre-Glacial and pre-Wisconsin topography. Pl. I shows the geological structure of the eastern half of the State and the distribution and directions of movement of the Green Bay and Lake Michigan glaciers of the late Wisconsin stage.

In this discussion the names of the several Paleozoic formations are used as in the Geology of Wisconsin, with the exception that those beds provisionally referred to the Lower Helderberg formation by Professor Chamberlin are now regarded as belonging to the Salina formation. Reference to these formations being merely incidental to the discussion of the drift features of the area, it is not considered advisable to discuss the proposed revision of the nomenclature.

In the northwestern part of the area shown on Pl. I are the pre-Cambrian highlands, composed of Archean and Huronian rocks. Lapping upon the eastern and southeastern slope of this nucleus are the Paleozoic formations, beginning with the Potsdam sandstone, of Cambrian age, and ending with the Hamilton beds, of Devonian age. These formations have easterly and southeasterly dips. As shown by the section of the Blue Mounds west of Madison, the Niagara and all the subjacent formations originally extended far beyond their present limits, if not quite across the southern part of the State. At present the Niagara formation, with the exception of a few small outlying remnants, is confined to a belt 40 to 50 miles in width bordering the shore of Lake Michigan. It is evident that pre-Glacial erosion denuded the eastern half of the State of hundreds of feet of rock. In consequence of this extensive denudation, the western marginal parts of the several rock formations of this part of the State outcrop in more or less irregular belts, generally parallel to one another, to the strike of the beds, and to the west shore of Lake Michigan. Thus, in traversing the area from west to east one ascends the geological scale. The following is the list of formations present:

Geological formations of southern Wisconsin.

Devonian period.
- Hamilton formation.
  - (Cement rock, blue and black shale.)

Silurian period.
- Salina formation.
  - (Thin-bedded, dolomitic limestone.)
- Niagara limestone.

Ordovician period.
- Cincinnati shale.
- Galena limestone.
- Trenton limestone.
- St. Peter sandstone.
- Lower Magnesian limestone.

Cambrian period.
- Potsdam sandstone.

Pre-Cambrian.
- Huronian quartzite.
- Igneous and metamorphic rocks.

The formation having the greatest influence on the deployment of the glaciers of eastern Wisconsin during the late Wisconsin invasion was the Cincinnati shale. This formation has an average thickness of about 200 feet, and is composed in its upper part chiefly of slightly indurated clay shales and limestones, while in the lower horizon are arenaceous and thin-splitting, brittle, slaty shales. As the result of this composition, wherever the heavy superjacent beds of Niagara dolomite were removed by erosion the poorly indurated beds of this formation were readily removed, and the erosion, thus localized, extended downward into subjacent Galena beds. A broad trough was thus formed, its bottom and long west slope of Galena limestone, and its east side a more or less abrupt escarpment in the beds of the Cincinnati group and the thick overlying beds of the Niagara group. On the borders of Green Bay and Lake Winnebago this escarpment rises to a height of about 400 feet above the rock bottom of the trough. Farther south the valley shallows by the thinning of the west margin of the Niagara formation and the less sharp erosion of the Cincinnati beds. Moreover, the region is so heavily covered with drift that even the exact location of the west margin of the Niagara and Cincinnati formations can not always be ascertained.

Owing to the extent to which the older drift formations of the State are covered by the later deposits, it is not evident to what degree this Green Bay-Lake Winnebago trough influenced the advance of the glaciers of the earlier stages. It is plainly evident, however, that this trough determined the direction of the flow of the Green Bay Glacier of the late Wisconsin stage, if, indeed, to

it was not due the actual differentiation of this part of the great ice sheet as a distinct glacial lobe. So also to the tributary valleys leading into this trough in southern Waukesha and Walworth counties was due the development of the Delavan glacial lobe, with the consideration of which this paper has to do.

The pre-Glacial topography, or, more properly speaking, the configuration of the rock surface beneath the drift, within the limits of the area treated in this paper, is shown on Pl. II with such accuracy and detail as the data at hand will permit. The terminal moraines of the late Wisconsin glaciers and the courses of the present streams are also traced, to show the relations.

The pre-Glacial Rock River Valley, in Rock County, contains 300 to 400 or more feet of drift. South of the Johnstown moraine the surface of the outwash deposit filling the valley is nearly flat. This surface rises from an elevation of 800 feet above the sea at the State line to 900 feet at the front of the moraine. The higher parts of the undulating tracts on the east and the west of this valley reach an elevation of 1,000 feet above the sea, so that the location of the broad valley and its tributaries is plainly marked. From the front of the moraine to Lake Koshkonong there are 400 feet or more of drift in the morainal belts which cross the valley, so that the presence of the pre-Glacial trough would hardly be suspected.

The rock first reached in the well[a] at the Rock County farm, 4 miles north of Janesville, is the Lower Magnesian limestone in the west slope of the pre-Glacial valley, at an elevation of about 635 feet above tide. In the Riverside farm artesian well, about 2 miles southwest of the city, the rock first struck, at an elevation of 560 feet above sea level, belongs to the same formation. In the fair grounds well and the water company's wells at Janesville the red shale of the Potsdam group was the first rock struck in the lower valley slope, at elevations of about 510 and 520 feet, respectively. No deep wells south of the moraine are so located as to reach the bottom of the valley, so that the full depth can only be conjectured. The elevation of this bottom is evidently less than 450 feet above the sea, but may not be below 400 feet at the State line. Professors Chamberlin and Salisbury, in their article on the driftless area of the upper Mississippi,[b] cite the fact that a well on the border of Lake Koshkonong shows the valley bottom to be at least 330 feet below the present level of Rock River, or only about 450 feet above the ocean. One well in the valley at Fort

[a] Elevations determined from topographic maps of United States Geological Survey.

Authorities for well records: Rock County farm well and Riverside farm well, E. Hindes, driller, Janesville, Wis.; Janesville fair grounds well, Geology of Wisconsin, vol. 2, p. 166; wells of Janesville Water Company, records at company's office; wells in Fort Atkinson and vicinity, data from Albert Hummell, driller, ex-Governor Hoard, McMillen Bros., Carl A. Becker, Mr. Bullock, Dewitt Wilcox, O. A. Howard, G. J. Hausz, Henry Ehlers, and Peter Young; well in Scuppernong Marsh, Robert Blackmore, driller, Palmyra, Wis.

[b] Chamberlin, T. C., and Salisbury, R. D., Preliminary paper on the driftless area of the upper Mississippi Valley: Sixth Ann. Rept. U. S. Geol. Survey, 1886, p. 223.

Atkinson, about 30 miles north of the State line, was reported as having reached the Potsdam sandstone in the bottom of the valley at an elevation of about 500 feet above sea level, while several wells in the same vicinity reach the rock at elevations ranging from 500 to 560 feet. These wells penetrated 200 to 330 feet of drift. Seven or 8 miles east of this place a well in the Scuppernong Marsh is said to have penetrated 270 feet of drift—i. e., to an elevation of 520 feet above the sea—without reaching the bottom of the valley. North of the moraine there is 200 to 330 feet of filling, and the valley is occupied by Lake Koshkonong and extensive marsh areas. The relations of the present stream to the pre-Glacial valley are shown on Pl. II.

East of the pre-Glacial Rock River Valley, and separated from it by a broad ridge of rock, is a broad valley that owes its location to the slight induration of the Cincinnati beds. The upper branches of this valley are traversed by Fox River between Waukesha and Big Bend, but the main valley contains no stream of importance. Since the position of the pre-Glacial valley is now most plainly marked by the low area within and adjacent to the towns of Troy and East Troy, in northeastern Walworth County, it may be conveniently referred to as Troy Valley.

The low tract in the adjacent parts of Waukesha and Walworth counties lies 100 to 200 feet lower than the crest of the Kettle Range and the undulating ground moraine tracts on the south, yet the pre-Glacial valley is so largely filled with morainal and outwashed drift, and the surface of this drift presents such a peculiar topography, that it scarcely impresses one as marking the position of a definite river valley. The present topography is that of a plain above which rise a few small undulating areas and in which are many irregular depressions of large and small extent, varying from 10 to 100 feet in depth, with abrupt gravel slopes, and occupied by marshy tracts and by more than a score of ponds and lakelets. Several wells show that the basin marks the location of a pre-Glacial valley cut through the marginal beds of Niagara limestone and those of the Cincinnati group. In Mr. Fred Andrews's well, 1¾ miles southwest of the village of Mukwonago, the first rock reached was shale at an elevation of about 540 feet above sea level. Upon this shale was 300 feet of drift. In Mr. Stephen F. Fields's well, 1 mile east of East Troy, the Galena limestone was the first rock struck, at an elevation of 530 feet above the sea, beneath 330 feet of drift; while McKee Brothers' well, 5 miles west of East Troy, penetrated 401 feet of drift before reaching limestone at an elevation of 480 feet.[a]

[a] Authorities for well records:
Andrews's well, Otto Hembrook, driller, Mukwonago: Fields's well, Arthur Smith, Burlington, in whose possession were samples of drillings, McKee Brothers' well, W. L. Thorne, driller, Whitewater.

While it is clear from these well records that there is here a very considerable pre-Glacial valley, the position of its outlet is somewhat open to conjecture. The valley appears to be too deep to have discharged into Rock River Valley by way of the valley between Palmyra and Fort Atkinson, now occupied by Scuppernong Creek and Marsh; moreover, the limestone has been reached at a sufficient number of points beneath the Kettle moraine and the outwash deposits on the east to make it almost certain that a continuous rock ridge 200 to 300 feet high separates the two basins. Like reasons appear to exclude connection with the valleys tributary to Rock River Valley in eastern Rock County. It seems to be equally sure that there was not an eastward discharge to the Lake Michigan basin. The most probable line of discharge is southward through Walworth County, as shown on Pl. II, yet this mapping is based on the general relations rather than on positive evidence furnished by the area itself. It was reported to the writer that a certain well 3 or 4 miles southeast of the village of Darien penetrated 150 feet of clay and 250 feet of gravel without reaching rock. This report was not verified, but if it is correct the rock at this place lies lower than 600 feet above tide.

At Elkhorn the city well entered the Cincinnati beds without any overlying Niagara limestone being encountered, whence it appears that the west margin of the Niagara formations lies east of that point. The removal of this protecting limestone must have exposed the underlying shale to extensive erosion west of Elkhorn, the same as farther north. That the shale was so eroded beneath the Lake Geneva basin to the south is shown by the record of the well drilled at the Yerkes Observatory, near the northwest shore of the lake. This well penetrated 405 feet of drift before reaching the shale at an elevation of 621 feet above the sea. Though the shale is usually 200 feet or more in thickness, 177 feet being penetrated by the Elkhorn well, but 33 feet were found overlying the Galena limestone at this point. It thus appears probable that the course of the Troy Valley is as shown on Pl. II.

From the head of Sugar Creek southward to Lake Geneva the present topography gives no indication of such a buried valley. The surface is gently undulating and ranges in elevation from 900 to 1,080 feet. If this be the real course of the valley, as there seems little reason to doubt, there must be from 400 to 600 feet of drift piled into it within the Darien moraine. The further extension of the Troy Valley to the south is doubtless beneath Big Foot Prairie, southward through McHenry County, Ill., where it may have joined the pre-Glacial Kishwaukee Valley, to which reference is made by Mr. Frank Leverett,[a]

[a] The Illinois glacial lobe: Mon. U. S. Geol. Survey, vol. 38, 1899, p. 485.

and its waters discharged to the old Rock River Valley somewhere south of Rockford.

Wells in the area surrounding Lake Geneva show that the lake lies in a partly filled pre-Glacial valley whose bottom is less than 640 feet above the sea—i. e., more than 220 feet below the present lake surface, or about 80 feet below the lake bottom at its deepest point. This valley evidently discharged westward, thus being tributary to the Troy Valley.

OLDER OR PRE-WISCONSIN DRIFT.

The relations of the drift deposited by the glacier of the later Wisconsin stage to that of the glaciers of earlier stages in southern Wisconsin, Illinois, and Iowa, and western Indiana, are shown on Pl. III. These relations are discussed in detail by Mr. Leverett in his monograph on the Illinois glacial lobe and need not be described here except as they affect the specific phenomena discussed in this paper. So far as the writer's investigations have extended, there is little or no decisive evidence as to the exact age of the pre-Wisconsin drift of southern Wisconsin, though it appears probable from Mr. Leverett's studies in Illinois that drift of the Illinoian stage, and possibly of the Iowan stage, is here represented.

That this so-called "older drift" is really older than the moraine-bordered drift was long ago shown by Professor Chamberlin and his associates of the Wisconsin and the United States geological surveys.[a]

The evidence of greater age is found in the greater depth of leaching and oxidation of the drift, in the greater degree of weathering of the surface bowlders, and in the greater amount of erosion and more advanced stage of development of drainage systems of these extra-morainal tracts than in the moraine-bordered areas.

All these tests are specifically applicable to the older drift of southeastern Rock County and southwestern Walworth County, which is the most closely related of the pre-Wisconsin drift sheets, in point of situation, to the deposits of the Green Bay Glacier and of the Delavan glacial lobe. The older drift is thoroughly leached of its calcareous elements to a depth of 3 or 4 feet, sometimes to a depth of 5 feet or more. Oxidation extends to a considerable depth, and the upper 3 or 4 feet is stained to a brownish or yellowish-brown color. Very generally the color of the upper one-half foot to 1½ feet of the drift is bleached to a dirty gray, and several inches of black humus usually coats the whole. Within the moraine-bordered areas the leaching occasionally extends to

[a] Geol. Wisconsin, vol. 1, 1882, pp. 271–272.

depths of 3 or 4 feet, but the depth is usually between 1 and 2 feet, while the oxidation is less marked than in the older drift.

The crystalline bowlders of the later drift area usually show little indication of disintegration, while the occasional blocks of Niagara dolomite are nearly as fresh in appearance as if just taken from the quarry. In the older drift area the occasional Niagara bowlders will hardly be recognized at first glance. Their granular weathered surfaces are dull grayish to buff, often made grotesquely irregular by deep solution pits, which in some cases extend nearly or quite through the blocks. It is only on fresh fracture that the familiar whitish, crystalline character of the Niagara limestone is seen. Incipient cracks frequently appear in the crystalline bowlders, and it is very common for light blows of the hammer to flake off shell-like pieces one-eighth to one-fourth of an inch thick from their rounded surfaces.

The erosional difference is also notable; the later drift surface shows very little post-Glacial modification. Marshes, lakes, and ponds abound. The topography is everywhere of the depositional type. Large tracts of easily eroded material show absolutely no erosional modification other than the slightest surface gullying. In the older drift area erosion has made considerable progress. Nowhere is there the thorough dissection seen in the oldest drift sheets; the topography is still very young, yet numerous little valleys, 1 to 3 miles in length, show 40 to 60 feet of erosion. Some of the tributaries reach back 10 to 11 miles, and the whole area is well drained.

On the other hand, all these evidences of atmospheric exposure fall far short of those shown in the oldest drift sheets. The degree of leaching and oxidation is moderate. The crystalline pebbles and bowlders in the body of the drift, with the occasional exception of the more basic varieties, are usually compact and solid. Even where some of the basic bowlders have disintegrated, the component minerals are but slightly decomposed. The pebbles of Niagara limestone are fresh and clean, while considerable gently undulating areas have not been trenched by erosion.

Considering these facts, it appears that the drift in question probably occupies a position in the series somewhere between the Kansan and the Wisconsin drift sheets—i. e., it is probably either Illinoian or Iowan. Mr. Leverett, who has wide acquaintance with the drift phenomena of the Mississippi basin, has correlated the upper part of this drift with the Iowan stage of glaciation. The reasons for this correlation are, he says—

"because of an apparent similarity with the Iowan drift of eastern Iowa in its connection with the great sheet of loess in the Mississippi basin. The loess overlaps this drift sheet only a short distance in Illinois and was deposited apparently while

the ice sheet was melting away, there being no clear evidence of an exposure of its till to protracted atmospheric action prior to the deposition of the loess."[a]

Concerning the thickness of the Iowa drift Mr. Leverett states[b] that in eastern Winnebago and Boone counties, Ill., the drift of Iowan age is known to have considerable thickness, possibly an average of 40 feet or more. On the whole, however, he considers it a liberal estimate to allow an average of 10 feet, both of till and of loess, as the product of the Iowan invasion in Illinois. Below this occurs the Illinoian drift.

In the southeastern part of Rock County, Wis., numerous exposures of the underlying rocks occur, and often wells find less than 40 feet of drift; but, on the other hand, many other wells show more than 100 feet of drift. In southwestern Walworth County thicknesses of 200 to 250 feet are known to occur. It is quite possible that here, as in Illinois, these thicknesses comprise two or more drift sheets.

The prevailing color of the older drift in the area east of Rock River is pinkish at the surface exposures, but at greater or less depths a more solid blue till is encountered. One well 3 miles southwest of Clinton Junction penetrated solid blue clay which was so dense and dry that it was necessary to pour in water to wet the drill until a gravel stratum was reached at a depth of 100 feet. Some wells penetrate considerable deposits of sand or gravel between thick deposits of clay. Others penetrate deposits of black muck. But sufficient accurate data have not yet been collected to show beyond doubt that these are the deposits of an interval of deglaciation separating two distinct drift sheets.

PEORIAN STAGE OF RECESSION OR DEGLACIATION.

PEORIAN SOIL HORIZON.

Mr. Leverett states[c] that extensive deposits of muck and peat occur in the base of the Wisconsin drift in northern Illinois, notably in McHenry, Dekalb, Lasalle, and Bureau counties, which are in all probability immediately underlain, in some cases at least, by Iowan drift. The early Wisconsin drift sheets have been so far overridden by the late Wisconsin glaciers in southeastern Wisconsin that clear evidence of the Peorian stage of deglaciation has not been found.

The occurrence of soil horizons and vegetal remains has been reported at a few points beneath the terminal moraine, and outwash deposits of the Green Bay and Delavan glaciers; but it is by no means certain that they were formed

[a] Leverett, Frank, The Illinois glacial lobe: Mon. U. S. Geol. Survey, vol. 38, 1899, p. 180.
[b] Op. cit., pp. 136 and 137.
[c] Op. cit., pp. 185–186.

during the Peorian interval. In their article on the driftless area,[a] Messrs. Chamberlin and Salisbury make the following reference to inter-Glacial deposits in this region, based on information furnished by Mr. Reynolds, of Johnstown:

"Beneath the overwash gravels that fringe the moraine in the Rock River Valley, there are considerable accumulations of vegetable matter. The wells of Johnstown, Rock County, sunk at various times during the last thirty years, have frequently penetrated these. The maximum depth charged with vegetable matter is several feet."

A well near the edge of the moraine, 4½ miles northeast of Johnstown Center, penetrated the following deposits:

Section of well near Johnstown Center, Wis.

	Feet.
Top soil	1
Quick sand and gravel	10
Blue clay	40
Gravel	179
Black soil	2
Limestone	18
Total	250

The "black soil" resting on the limestone may be pre-Glacial rather than inter-Glacial.

Mr. W. H. Featherstone's well on the extreme frontal margin of the Darien moraine, 3 miles northwest of Walworth, penetrated the following deposits:

Section of the Featherstone well, near Walworth, Wis.

	Feet.
Clay	6
Reddish gravel	18 to 20
Yellow sand	2
Hard blue clay	42 to 44
Black quicksand	7 to 8
Total	80

The water from the "black quicksand" tasted like marsh water and was said to have had at first a very disagreeable odor. The margin of the Darien moraine of the late Wisconsin glacier at this point overlaps the older drift with no intervening outwash and, so far as known, with no interpolated drift of early Wisconsin age. The well curb stands but 20 or 30 feet above the level of the older drift outside of the moraine, so that it is quite as possible that the black humus marks the Sangamon soil horizon as that it was deposited during the Peorian interval.

[a] Chamberlin, T. C., and Salisbury, R. D., Preliminary paper on the driftless area of the upper Mississippi Valley: Sixth Ann. Rept. U. S. Geol. Survey, 1886, p. 264.

WISCONSIN STAGE.

EARLY WISCONSIN GLACIATION.

MARENGO RIDGE AND ASSOCIATED MORAINAL DEPOSITS.

The distribution of the moraines in Illinois, indicating the deployment of the ice during the earlier advances of the Wisconsin glaciers, is shown on Pl. III, which is compiled from data obtained by Mr. Leverett. These successive drift sheets so overlap in the northern part of the State that, in northern Kane County, the Bloomington and Marseilles moraines connect with a broad morainal tract whose component parts have not thus far been satisfactorily differentiated. The outer or western border of this composite belt is occupied by a somewhat distinct moraine, called the Marengo Ridge.

Near the village of Hampshire, in northwestern Kane County, the Marengo Ridge passes by the eastern end of the outer ridge of the Bloomington morainic system in a course nearly normal to it, and thence northward to the vicinity of Walworth, Wis., a distance of 30 to 35 miles, constitutes the outer moraine of the early Wisconsin series.[a] Mr. Leverett states[b] that the correlation of this ridge with the moraines farther south can scarcely be said to be settled. Several interpretations are suggested by the phenomena, no one of which he considers better sustained than the others.

By the first interpretation the Marengo Ridge is considered the continuation of the Bloomington system; by the second it is made later than the outer ridge of the Bloomington system, which it would thus be considered as having overriden; by the third the outer ridge of the Bloomington system is considered to pass across the Marengo Ridge and to join the composite belt lying east of that ridge, thus referring the latter ridge to an earlier stage than the Bloomington moraine.

Between the Marengo Ridge on the west and Fox River on the east the composite belt, 8 to 15 miles in width, is generally morainic. In this portion also satisfactory correlations with the more clearly differentiated moraines in the districts to the south have not yet been established. Concerning these correlations Mr. Leverett writes in part as follows:[c]

"Two quite distinct interpretations have been suggested in the course of the investigation. By the first interpretation this portion of the composite belt is made to be a continuation of the inner part of the Bloomington morainic system, which connects with it near Elburn. The very strongly morainic tract immediately northeast of Elburn would, in this case, be situated at a sharp bend or reentrant angle in the ice margin, and this may account for its greater ruggedness.

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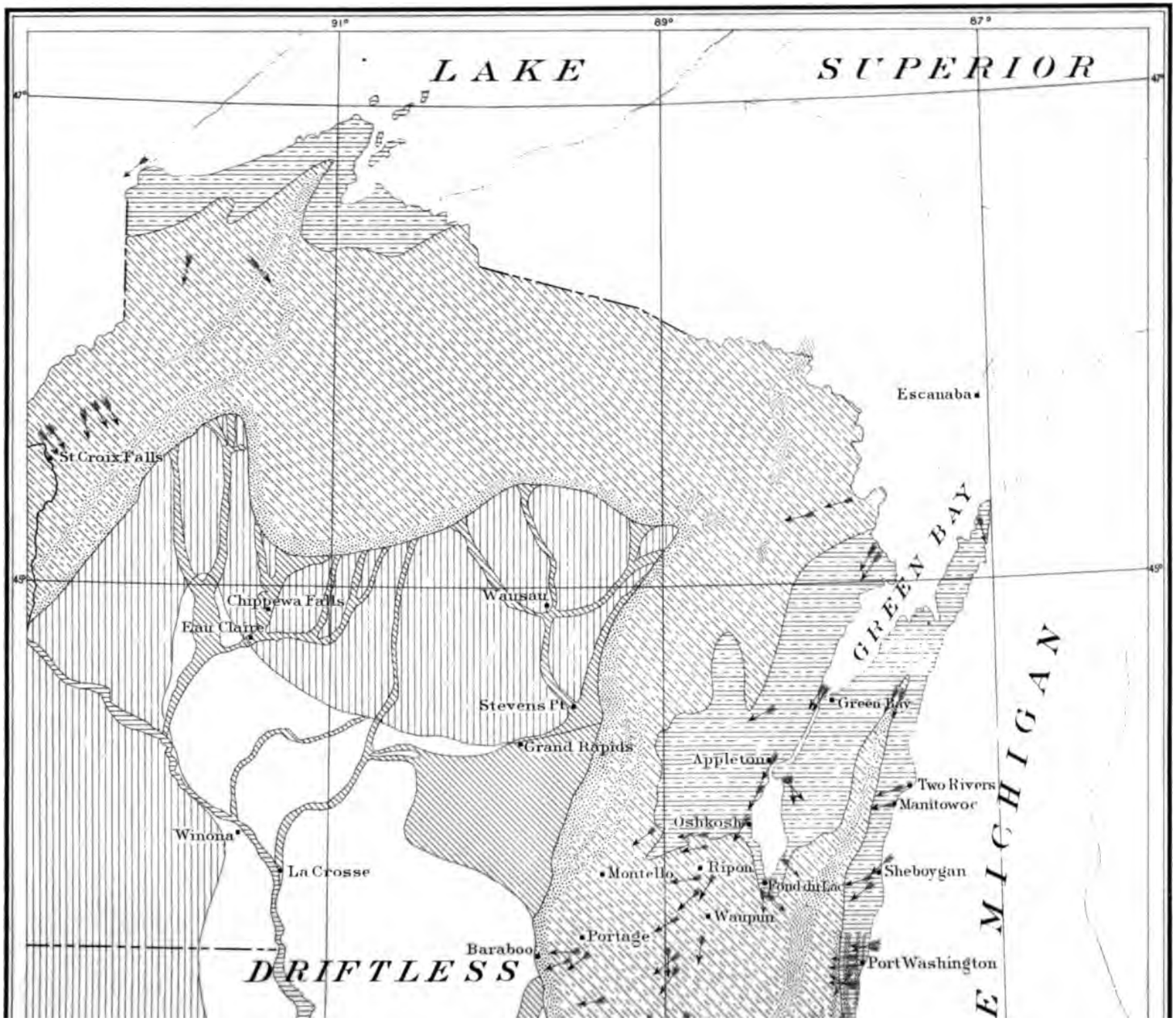
[a] Leverett, Frank, The Illinois glacial lobe: Mon. U. S. Geol. Survey, vol. 38, 1899, p. 290.
[b] Op. cit., pp. 295–296.
[c] Op. cit., pp. 302–304.



LEGEND

Probable temporary lake areas

Lake Kankakee

Lake Chicago area, so far as correlation has been made; outlets of lakes Chicago, Agassiz, and Maumee

Red pebbly clays (partly lacustrine, partly probably glacio-lacustrine) and associated lacustrine deposits not fully correlated with the deposits of Lake Chicago

Sand and gravel plains and terraces, mostly outwash deposits of Wisconsin age, including some lacustrine deposits

Late Wisconsin drift sheets

Early Wisconsin drift sheets

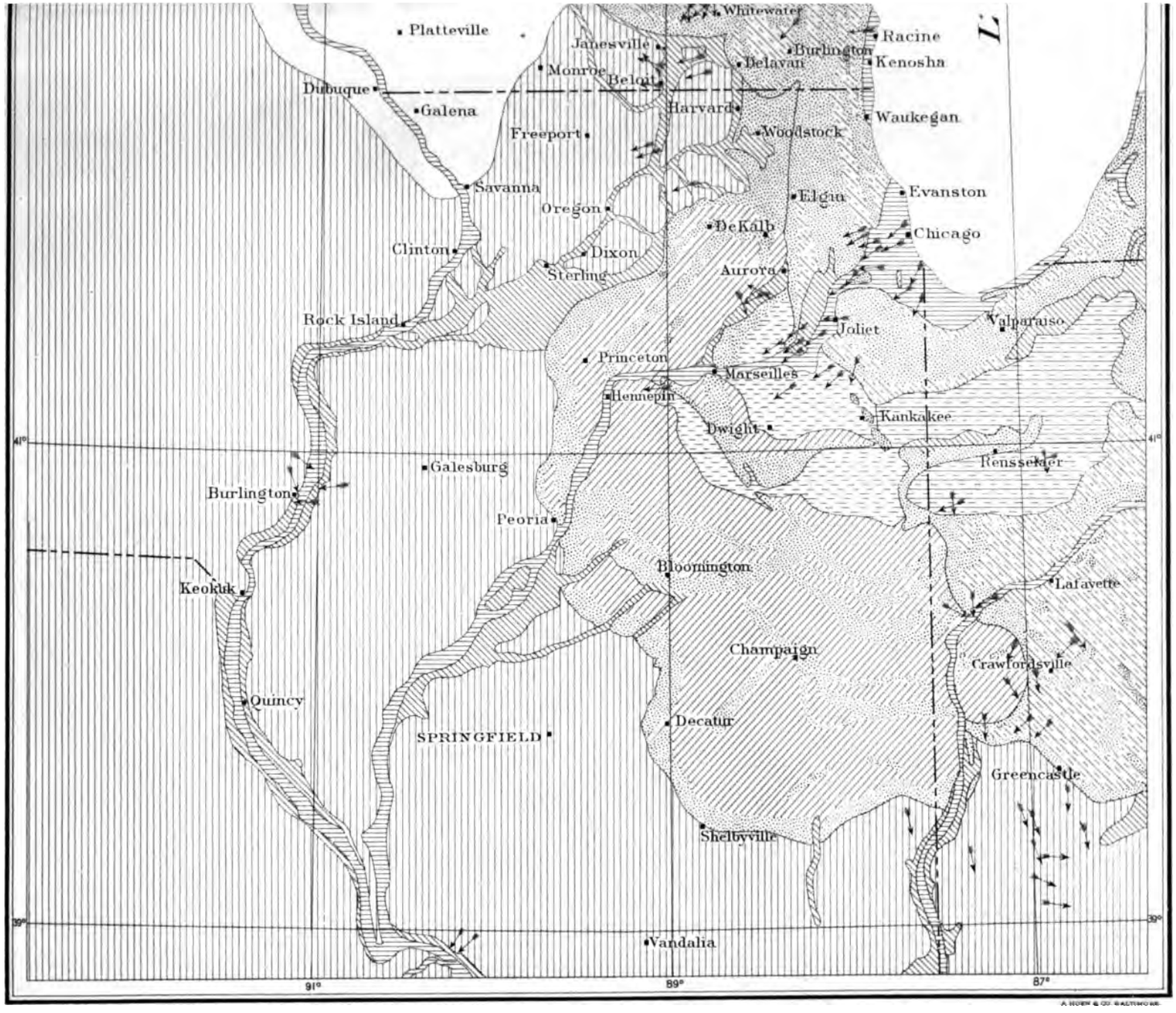
Glacial ridges, chiefly moraines of the Wisconsin glaciers

Pre-Wisconsin drift

Driftless, except on the northern borders of the area

Glacial striæ

Note.—Data for that part of the glaciated area of southeastern Wis-



Map of the Quaternary Formations of Wisconsin, Plate II, of Atlas of Wisconsin Geological Survey, T. C. Chamberlin, Chief Geologist, 1881, and from the Quaternary Map of the Driftless Area and Environs, by T. C. Chamberlin and R. D. Salisbury, Plate XXVII, of Sixth Annual Report U. S. Geological Survey, 1885.

Data for Illinois and adjacent parts of Indiana, Michigan, Iowa, and Missouri, from the Glacial Map of the Illinois Ice Lobe, by Frank Leverett, Plate VI, of Mon. U. S. Geological Survey, Vol. XXXVIII, 1899.

QUATERNARY MAP OF WISCONSIN, ILLINOIS, AND ADJACENT AREAS

BY

WILLIAM C. ALDEN

Scale

0 5 10 20 30 40 50 60 70 miles

1903

"The bulk of the Bloomington system is not greatly different from that of the composite belt west of Fox River, and presents no obstacle to this interpretation. The topography of the composite belt is much sharper in expression than that of the Bloomington system, but changes of topography have been found to occur in other belts to as marked a degree as in this instance. * * *

"By the second interpretation this portion of the composite belt is thrown into the late Wisconsin series of moraines, and its continuation found in the bowlder belts and feebly developed morainic tracts lying outside of the Valparaiso morainic system in Kane, Kendall, Grundy, and Kankakee counties. The belts can be traced into a reasonably close connection with the southern end of the undulatory belt in southern Kane County. There seems, therefore, no formidable gap to bridge in making this correlation. The greatest obstacle to the interpretation appears to be found in the abrupt change in bulk which the moraine presents in the district east of Elburn. From this point southward a thickness of only 20 or 25 feet is presented by this moraine where best developed, while to the north the thickness averages more than 100 feet. The expression also is much stronger north than it is south from this line."

He further suggests a combination of these interpretations by which the great bulk of the portion north of Elburn is referred to the Bloomington morainic system, while the slight moraine in southeastern Kane County is made the result of the late Wisconsin invasion, in which the ice would be supposed to override the composite belt without greatly modifying its character. The relation of the Kaneville esker northwest of Aurora, Ill., he thinks, however, throws the balance of evidence in favor of correlation with the Bloomington system.

This latter correlation also is more in accord with the writer's observations on the relations of the Genoa and Darien moraines of the Delavan lobe, which clearly are of late Wisconsin age, to this composite morainal belt in the vicinity of the State line.

Near Elgin, Ill., the combined Marseilles moraine and Minooka Ridge separate from the eastern part of this composite belt. In Kendall County this ridge divides into the component moraines, of which the Marseilles moraine is referred to the early Wisconsin group, while the Minooka Ridge is provisionally correlated with those of the late Wisconsin glacier. From northern Kendall County northward the Marseilles moraine appears to have been overridden by the later advance.

The equivalence of the Valparaiso morainic system to the eastern portion of the composite belt is established beyond doubt. Mr. Leverett states[a] that it probably should include all of the composite belt north of Elgin on the east side of Fox River and possibly also a small part west of that stream. This also agrees with the writer's observations on the Wisconsin side of the State line.

[a] Op. cit., pp. 304–305.

RELATIONS BETWEEN THE MARENGO RIDGE AND COMPOSITE MORAINIC BELT IN ILLINOIS AND THE MORAINES OF THE DELAVAN GLACIAL LOBE IN WISCONSIN.

The relations of the moraines in northern Illinois being as above stated, it is of some importance to determine how the moraines of Wisconsin are related to the Marengo Ridge and the associated composite morainal belt. In brief, the relationship may be stated as follows:

The Marengo Ridge extends about 1½ miles into Wisconsin south of the head of Lake Geneva. Here it ends in a long north slope which appears to be due to its dropping down into the depression formed by the confluence of the pre-Glacial Geneva and Troy valleys (Pl. II).

Where the Darien moraine crosses this trough west of Lake Geneva, instead of being depressed its crest reaches an elevation higher than at any point northwestward to Richmond. North of the Darien moraine a broad ridge swings about the head of the Geneva basin (Pl. XIV). North of Williams Bay and the head of Lake Como, in the line of the continuation of this ridge, the deposits of the Elkhorn moraine reach the highest elevation in this part of the State—1,140 feet above the sea—though farther north this moraine is a very inconsiderable topographic feature.

From these facts it appears very probable that the Marengo Ridge in descending into Troy Valley was deflected slightly toward the west. It dammed Geneva Valley near the site of the village of Walworth, and thence swung toward the northeast, ascended the east slope of Troy Valley, and surmounted the Niagara formation.

This ridge so largely filled Troy Valley near Walworth that, when the Darien moraine was deposited across the drift-filled valley, no depression of its crest occurred, but instead the crest was higher than to the northwest. The elevation north of Williams Bay is well accounted for by supposing that the Elkhorn moraine here crossed the Marengo Ridge as the latter ascends the pre-Glacial slope.

The Genoa, Darien, and Elkhorn moraines lie in curves transverse to the trend of the Marengo Ridge and of the whole composite morainal belt of McHenry County, Ill., and, if the writer's interpretations are correct, the northward extensions of these earlier morainal deposits were overridden by the Delavan lobe of the late Wisconsin Glacier, which formed the transverse moraines.

The ice movement in the southern part of the Delavan lobe, as elsewhere shown, varied from a direction normal to that of the glaciers forming the earlier morainal systems to a direction oblique to that of the earlier movement. That is to say, while the early Wisconsin glacial movements were from east to west

across Lake and McHenry counties, Ill., the direction of the movement of the southern part of the Delavan lobe of the late Wisconsin stage varied from south to southwest. The change in direction of movement in this small lobe of the late Wisconsin glacier was due to local conditions and is insignificant in comparison with the shifting of the axes of the great glacial lobes in Illinois. This is especially true when it is considered that the movement in the Lake Michigan Glacier across Racine and Kenosha counties, Wis., and Lake County, Ill., agreed with that of the earlier glaciers in being from east to west. Nevertheless it is worthy of note that in the southern half of Walworth County, Wis., there was a discordance between the movement in the Delavan lobe of the late Wisconsin Glacier and the movement of the early Wisconsin glaciers in northern Illinois, which discordance is in agreement with the shiftings of the ice lobes on a much grander scale in Illinois. It is on the basis of this shifting of the ice lobes in Illinois and Indiana that the distinction has been made between the earlier and later advances of the glaciers of the Wisconsin stage. There is no evidence of a great difference in age. It is not known to what extent the earlier glaciers of the Wisconsin stage wasted away before the readvance was inaugurated. Illinois was not improbably freed from ice, and the same may have been true of Wisconsin. The change in conditions appears to have been sufficient at least to result in the notable shifting of the ice lobes above mentioned.

LATE WISCONSIN GLACIATION.

OUTLINE OF THE PROCESS OF GLACIATION AND DEGLACIATION OF THE AREA.

Before taking up the detailed discussion of the several moraines and associated outwash deposits of the late Wisconsin glaciers it may be well to give an outline of the history. It is not possible to determine in very much detail the history of the advance of the glaciers, because during the advance and subsequent melting of the ice the record was made obscure. Near the limit of the advance of the ice the deposits, not having been again overridden, are more readily deciphered, and, as much more of the record remains, the later history seems to be more complicated than the earlier. Whether it really was so may well be questioned.

The area covered by the late Wisconsin glaciers in Wisconsin and adjacent parts of the neighboring States at the time of their maximum extension is shown on Pl. III, and their extent in the part of southeastern Wisconsin under discussion is shown in more detail on Pl. IV. The fronts of the Green Bay and Lake Michigan glaciers were in conjunction along a line which ran northeastward from the vicinity of Richmond, and along this line was formed the interlobate Kettle moraine. Near Richmond the ice fronts diverged; that of the Green Bay Glacier lay along the Johnstown moraine to the west, and that of the Delavan lobe of

the Lake Michigan Glacier lay along the Darien moraine southeastward to the vicinity of Walworth, and, beyond this, along the Genoa moraine, a branch of the main terminal moraine. The west front of the main Lake Michigan Glacier lay to the east, along the Valparaiso moraine, near the line of Fox River. From these melting ice fronts copious streams of water poured down the pre-Glacial Rock and Troy valleys, filling them with vast amounts of sand and gravel. While the ice fronts yet held their advanced positions through most of their extent, the south front of the Delavan lobe was melted back to the main terminal moraine, which lay south of Lake Geneva and ran thence northeastward to the vicinity of Burlington. The escaping waters then cut an outlet through the outer moraine near Genoa Junction, which is now occupied by Nippersink Creek.

On the completion of the Darien and Johnstown moraines, a stage of excessive wastage ensued, the marginal parts of both the Delavan and Green Bay lobes being eaten away. Whether the extent of this retreat of the ice fronts is measured by the distance between the outer moraines and those next formed, or whether there was a further retreat followed by a readvance to these moraines, is not known. At the next stage the glaciers appear to have had the extension shown on Pl. V. The margin of the Delavan lobe lay along the Elkhorn moraine, while the Green Bay Glacier occupied the Milton moraine, the junction of the two ice fronts having been moved to the vicinity of Lagrange Center, about 9 miles northeast of its former position. For about 3 miles along the front of the Green Bay Glacier the water discharged into the low area behind the Darien moraine, where it formed the outwash plain on which stands the village of Heart Prairie. This water and that from the west front of the Delavan lobe cut an outlet through the Darien moraine and the bordering gravel terrace and escaped to the newly formed Rock River. This latter stream originated when the water from the Green Bay Glacier, ponded behind the Johnstown moraine, broke over a sag in the morainal crest and began the erosion of a valley in the gravel plain along the line of the present stream. Probably about this time also lakes Geneva, Delavan, and Como were formed.

Again the rate of wastage gained the ascendency and the retreat of the ice fronts was resumed and the margin of the Delavan lobe was gradually forced back across the elevated area east of Elkhorn. (Pl. X.) A part of the waters escaped southward to the Nippersink outlet at Genoa Junction, while the rest escaped by the Turtle Creek outlet near Delavan. A part of this latter flow, probably concentrated by a sag in the drift, began the excavation of Sugar Creek Valley through the high area east of Elkhorn. The Green Bay Glacier still stood snugly pressed against the interlobate Kettle moraine at least as far south as Palmyra, though the ice on the east was melting away. The discharge of

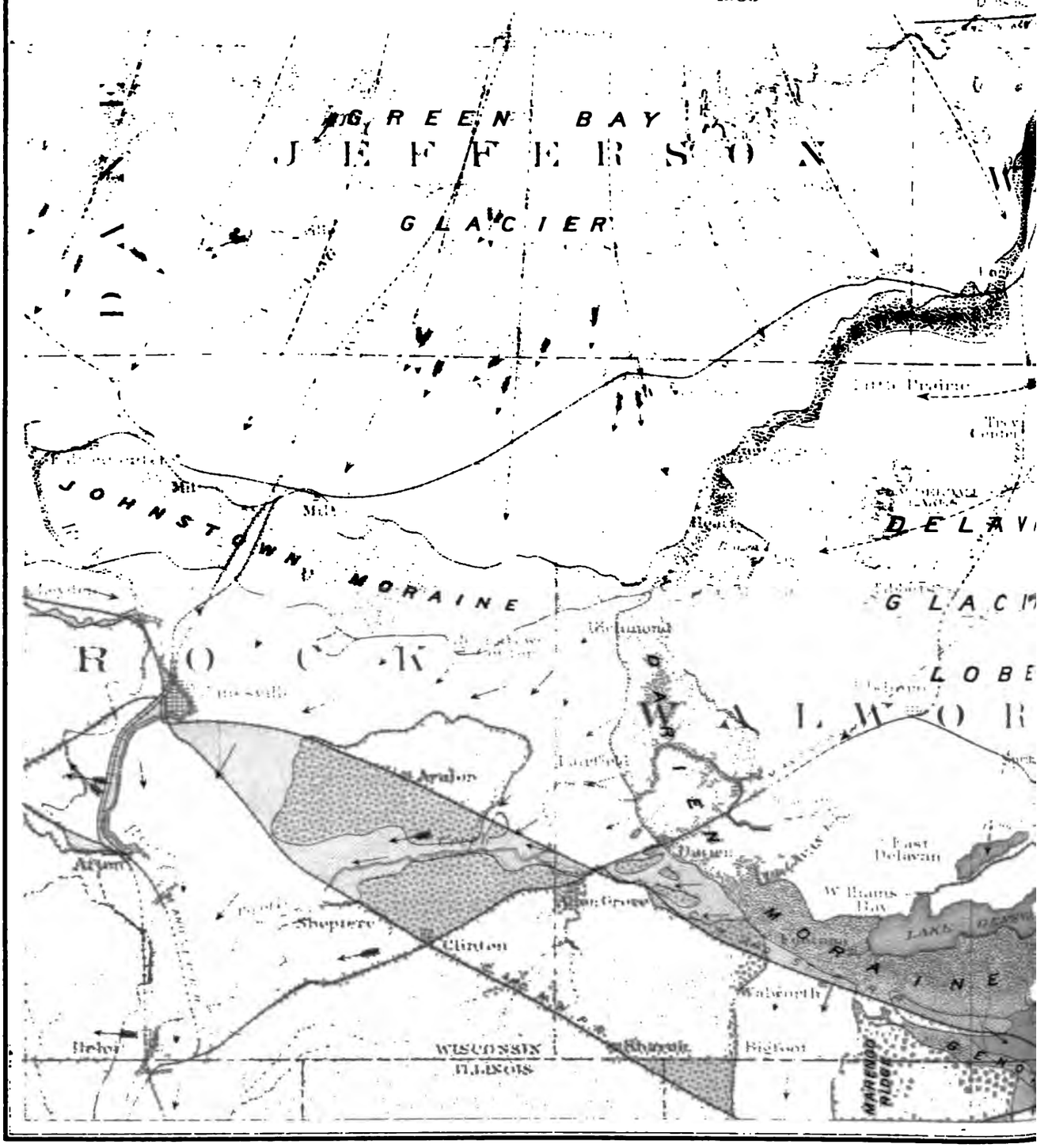
MAP OF A PORTION OF SOUTHEASTERN WIS

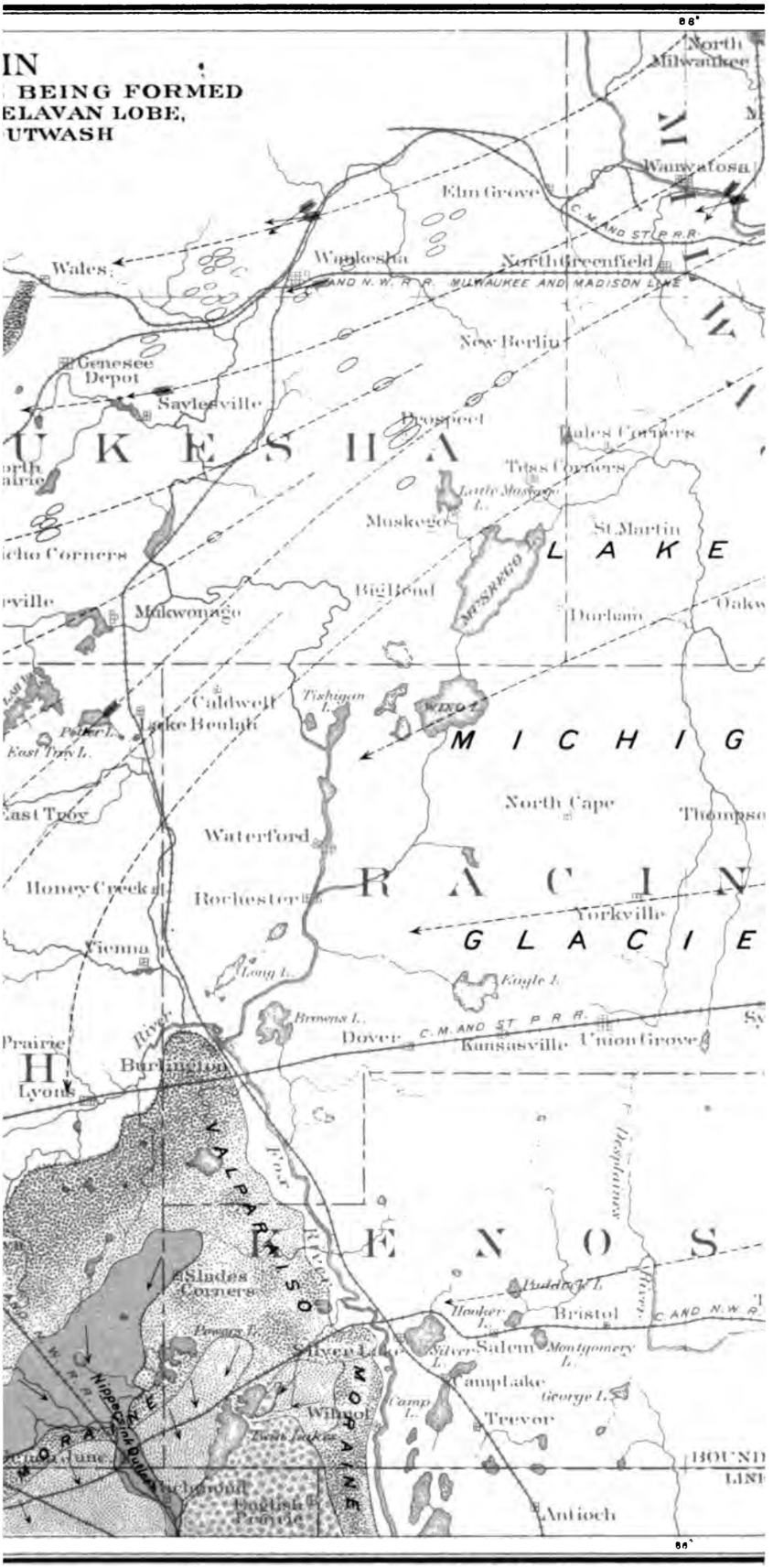
AT THE TIME THE GENOA, DARIEN, AND JOHNSTOWN TERMINAL MORAINES
SHOWING THE RELATIONS OF THE LAKE MICHIGAN GLACIER, INCLUDIN
TO THE GREEN BAY GLACIER AND OF THE MORAINES AND ATTE
DEPOSITS TO THE EARLIER DRIFT DEPOSITS

BY WILLIAM C. ALDEN

Scale
1 0 1 2 3 4 5 6 7 8 9 10 miles

1903




IN
BEING FORMED
ELAVAN LOBE,
UTWASH
North Milwaukee
Wauwatosa
Elm Grove
C. M. AND ST. P. R. R.
Wales
Waukesha
North Greenfield
AND N. W. R. R. MILWAUKEE AND MADISON LINE
New Berlin
Genesee Depot
Sayleswille
Prospect
Eales Corners
Tess Corners
Little Muskego L.
Muskego
St. Martin
LAKE
Big Bend
Muskego
Durham
Oakw
Caldwell
Lake Beulah
Fish Lake
WIS. C. T.
MICHIG
East Troy
North Cape
Thompso
Waterford
Honey Creek
Rochester
RACIN
Yorkville
GLACIE
Vienna
Long L.
Eagle L.
Browns L.
Dover
C. M. AND ST. P. R. R.
Kansasville
Union Grove
Prairie
Burlington
Lyons
VALPARAISO
Four Mile River
Pebble Creek
ENOS
Slades Corners
Powers L.
Bushnell L.
Hooker L.
Bristol
C. AND N. W. R.
Silver Lake
Silver L.
Salem
Montgomery L.
Camp Lake
George L.
Camp L.
Wilmot
Trevor
Twin Lakes
MORAINE
Nippersink Outlet
BOUND
LIN
Antioch
English Prairie

waters from the converging ice fronts thus built up the first or upper terrace which borders the Kettle moraine on the east, from its junction with the Elkhorn moraine to a point 4 miles northeast of Eagle. West of Palmyra but meager morainal deposits are now exposed, so that the exact position of the south front of the Green Bay Glacier is in doubt.

The wasting of the glaciers continued until their margins had about the relations shown on Pl. XIII. As far north as the vicinity of Wales the Green Bay Glacier now ceased to pour its waters over the Kettle moraine into the province of the Delavan lobe on the east. Its southeast front perhaps lay along the moraine running northward from the vicinity of Palmyra. The waters from the Delavan lobe, having cut down the Sugar Creek Valley as low as the channel leading to the Turtle outlet, and the wasting of the ice having cleared the valley, a new outlet for the waters from the north was opened, allowing them to escape to the Nippersink outlet at Genoa Junction. This new channel having a greater fall than that by way of the Turtle outlet, the latter was abandoned and the accelerated flow cut away much of the morainal and terrace deposits east of Eagle and formed a second and lower terrace.

The formation of the third and lowest gravel terrace in southwestern Waukesha County and northeastern Walworth County, which marks the next distinct stage of the glacial retreat, occurred when the retreating margin of the Delavan lobe cleared the Fox River Valley as far north as Burlington and the valley of Honey Creek above the latter place, thus giving a new and still lower outlet for the glacial waters, which then began, with renewed energy, the excavation of the gravels of the second terrace. About this time the retreating front of the Green Bay Glacier must have made a stand at the Hebron moraine, its last halt within the area under discussion. The further history of the wasting of this glacier is not considered in this paper.

At length the Delavan lobe was entirely wasted away. This appears to have been accomplished while yet the west front of the main Lake Michigan Glacier occupied the Valparaiso morainic system bordering the line of the Fox River southward to the State line. From this time the whole west front of the Lake Michigan Glacier retreated eastward across the area. Stages in this retreat are marked by the ridges of the lake border morainic system.

With the withdrawal of the glacial margin into the basin of Lake Michigan the waters of a lake which occupied the basin, expanding as the ice disappeared, produced a series of phenomena which are discussed under the history of Lake Chicago (pp. 68–72). At the Glenwood stage the waters of this glacial lake stood about 60 feet higher than the present lake level and discharged through an outlet in the vicinity of Chicago, Ill. Following this was a low-water stage, due probably to

the farther retreat of the glacier and the opening of a lower outlet to the northeast. Following this low-water stage the waters again rose, this time to a level about 40 feet above the present lake. This constitutes the Calumet stage. Associated either with the Calumet stage or with the latter part of the Glenwood stage, a readvance of the glacier southward to the vicinity of Milwaukee is believed to have occurred. To the peculiar combination of conditions resulting from lake action and from the crowding of this glacier upon the land is referred the deposition of a red clay which overlies the lacustrine deposits from the vicinity of Milwaukee northward. Certain evidence has developed indicating the possible occurrence of a second low-water stage of Lake Chicago following the Calumet stage. At the final stage, the Toleston, the lake stood 20 feet or more higher than the present lake. The final opening of a northeast outlet lower than the Chicago outlet merged the history of Lake Chicago into that of Lake Michigan.

DEPLOYMENT OF THE GREEN BAY AND LAKE MICHIGAN GLACIERS AND THE ORIGIN OF THE DELAVAN LOBE.

As the ice of the later advance of the glaciers of the Wisconsin stage invaded the borders of Wisconsin, the troughs formed by the erosion of the soft beds of the Cincinnati formation became the controlling factor in the separation and deployment of the Green Bay Glacier, and, in the southeastern counties, in the formation of the Delavan lobe of the Lake Michigan Glacier. The pre-Glacial valleys seem not to have been obliterated by the earlier drift deposits.

While the Green Bay-Lake Winnebago trough was competent to give direction to the Green Bay Glacier, it was not sufficiently deep to confine the deployment of the glacier to its immediate limits. On the west the ice spread out 60 to 70 miles from the main axis of the lobe. In western Shawano County and eastern Marathon County, where the ice encroached upon the Archean highlands, the marginal deposits lie at an elevation nearly 1,000 feet higher than the bottom of Green Bay, opposite Sturgeon Bay. Farther south the ice, after ascending the gentle slope of the Galena formation, reached the southward and southwestward discharging valleys eroded in the St. Peter and Potsdam sandstones, which doubtless facilitated the advance in that direction, so that the ice extended to northern Rock County and northwestern Walworth County, where the Johnstown terminal moraine was formed.

On the east the deployment of the ice was confined to 20 to 30 miles from the axis of the lobe. This limitation was not, however, due to the escarpment formed by the west margin of the Niagara limestone and the underlying shales, since southward to southwestern Waukesha County the ice overrode the escarpment and began to descend the gentle eastward slope of the Niagara formation.

The Lake Michigan Glacier advanced southward along the lake basin, and on the west deployed laterally into the eastern counties of Wisconsin, where its west front moved 15 to 30 miles up the gentle rock slope. Where the opposing fronts of the Lake Michigan and Green Bay glaciers met on this slope the advance ceased and the famous interlobate Kettle Range, or Kettle moraine, was formed.

In Illinois and Indiana the Valparaiso morainic system is believed to mark the limit of the advance of the Lake Michigan Glacier at this stage. The relations of certain outlying features have not been clearly determined.

In southern Waukesha and Walworth counties, Wis., before reaching the limits of its advance the west front of the Lake Michigan Glacier crossed the divide and entered Troy Valley, shown on Pl. II. This valley, through Walworth County, has a breadth of 10 to 15 miles and its bottom lies 300 to 500 feet below the level of the higher parts of the rock surface on either side. To what extent this pre-Glacial valley was filled with drift of the earlier ice invasions is not known, but that it offered a channel of easy flow to the ice nearing the limits of its advance on the gently rising slope of the Niagara formation is apparent from the fact that down this trough the ice advanced to the vicinity of the villages of Richmond, Darien, and Walworth, a position nearly 25 miles farther west than the limit reached in Illinois. The village of Delavan, in western Walworth County, stands not far from the most southwesterly point reached by this glacial lobe, so that the name Delavan lobe is a convenient term by which to designate this part of the Lake Michigan Glacier.

Though the origin of the Delavan lobe appears to have been due in large part at least to the channel of easy flow offered by the Troy Valley to the ice nearing the limit of its advance on the gently rising slope, the lobe, once initiated, was not confined to the limits of the valley, but spread southward over a more elevated tract between Elkhorn and Burlington and over the lower area to the south, in which is the Geneva Valley, until its south front halted near the State line along the northern border of the composite morainal belt formed by the earlier glacial advances of the Wisconsin stage.

DIRECTIONS OF ICE MOVEMENT IN THE GLACIERS.

Within the southern part of the area of the Green Bay Glacier the directions of the ice flow radiated toward the crescentic margin. The radiation is shown by the striæ on the rock, and more strikingly by the strongly developed drumlin topography of the ground moraine. In southwestern Waukesha County, northwestern Walworth County, and southeastern Jefferson County the direction varied from southeast to south, toward the interlobate Kettle moraine (Pl. IV). Some

of the striæ observed in southern Jefferson County and in northeastern Rock County have a more southwesterly trend than the neighboring drumlins. It is possible that they were formed during an earlier glacial advance, or they may be merely local variations in the direction of the movement.

The directions of the ice movement in the Lake Michigan Glacier are shown by similar phenomena (Pls. IV and XIV). In Waukesha County, from the vicinity of the village of Genesee northward, the movement was westward toward the Kettle moraine. Striæ observed 1½ miles east of Genesee range from S. 80° W. to S. 94° W. Those seen at Hadfield's quarry, north of Waukesha, range from S. 58° W. to S. 81° W.

The southwestern diversion down Troy Valley is shown by obscure striæ observed by Professor Chamberlin[a] 3 miles south of Mukwonago which have a trend S. 45° W. to S. 50° W.; by the trend of the drumloidal hills and elongated ridges of the ground moraine of southeastern Waukesha County, which is S. 50° W. to S. 60° W., and by striæ observed in several exposures in the vicinity of Milwaukee which range from S. 19° W. to S. 71° W.

In Racine and Kenosha counties the movement was again more westerly. Striæ observed at Horlick's quarry, northwest of Racine, range from S. 83° W. to S. 93° W.

In the Delavan lobe, while the axial movement was southwestward, there was doubtless a fan-like deployment of the ice such as occurred on a much grander scale in the Green Bay Glacier. This is indicated by the looped disposition of the moraines, but unfortunately there are no rock exposures so situated as to demonstrate the divergent movement. Certain drift ridges between the villages of East Troy and Waterford have a more southerly trend than the striæ observed south of Mukwonago, as though the flow was there diverging toward the south.

Certain disturbances in the rock layers observed by Professor Chamberlin[b] at the quarry west of Burlington indicate that the direction of the ice movement there was southerly.

OUTER TERMINAL MORAINES AND ASSOCIATED PHENOMENA.

GENOA TERMINAL MORAINE.

The Genoa moraine should probably be considered a branch of the Darien moraine. Northwest of the head of Lake Geneva the latter marks the limit of the advance of the Delavan lobe. The ice front appears to have continued here after it had withdrawn from the Genoa moraine to that part of the Darien moraine east of the head of Lake Geneva.

[a] Geol. Wisconsin, vol. 2, p. 204. [b] Op. cit, p. 204.

Excepting that part within 3 miles of Genoa Junction, the Genoa moraine has a weak and rather equivocal development. It is the strong development near Genoa Junction which gives the name to the moraine. In Southern Walworth County, as has been indicated, the bulky Marengo Ridge ends in a long north slope where it drops down into the pre-Glacial Troy Valley at its junction with the pre-Glacial Geneva Valley. Beginning at a point 1 mile south of the village of Walworth a narrow and fairly well defined belt of morainal topography is seen bordering the east margin of Big Foot Prairie. This belt may be traced up the slope to the south and thence southward as the crest of the Marengo Ridge. A short distance east of the northern extremity of this belt a second, milder belt of sags and swells, with occasional well-marked gravel knolls and kettle holes, separates from the main part of the Darien moraine, south of the western end of Lake Geneva, and may be traced with some discontinuity southeastward across the State line to the village of Hebron, Ill. One and one-half miles northwest of Hebron the valley of Nippersink Creek, which to the northeast and to the southwest is marked by broad marshy flats, is occupied by a deposit of morainal gravels. From the vicinity of Hebron this belt may be traced eastward and northeastward into Wisconsin again, along the south border of the marshy valley of Nippersink Creek. One-half mile north of Genoa Junction it is cut through by the creek.

From the second crossing of the State line to the valley of Nippersink Creek, near Genoa Junction, the Genoa moraine is strongly developed. The abrupt, ice-contact face rises 60 to 80 feet above the marshy tract on the north, and its crest is broken by abrupt knolls and ridges of gravel alternating with kettles, many of which are large and deep. In the vicinity of Hebron, Ill., several wells within this belt have penetrated 60 to 70 feet, principally of gravels. One well, west of Genoa Junction, penetrated 139 feet, principally sand and gravel. East of Nippersink Creek the moraine may be traced northeastward for a mile by a narrow gravel ridge pitted with kettles, which forms the crest of a broader ridge apparently of till. Beyond this, again, the moraine is not so well defined.

In western Kenosha County the converging Genoa and Valparaiso moraines are much alike in character. The whole belt is interlaced with irregular depressed areas, mostly marshy, some containing tamarack swamps, two of them occupied by Power and Lilly lakes. Within these depressions, surrounding them, or alternating with them, are equally irregular hills, ridges, and hummocky deposits of gravel. Reliefs of 60 to 100 feet are frequent.

In the interlobate angle in southwestern Kenosha County, between the converging south front of the Delavan lobe and west front of the Lake Michigan

[illegible]

[illegible]

[illegible]

extensive deposit of sands and gravels which are frequently exposed beneath a thin coating of clay.

ABANDONMENT OF THE GENOA MORAINE AND RELATIONS OF THE ICE FRONTS.

The deposition of the Genoa moraine and accompanying outwash deposits was followed by the melting away of 3 or 4 miles of the southern border of the Delavan lobe, so that the south front of the ice withdrew to that part of the Darien moraine lying between southwestern Racine County and the head of Lake Geneva. Elsewhere the ice margins appear to have continued at their outer moraines. Between the villages of Walworth and Richmond the southwest front of the Delavan lobe continued at the Darien moraine. From Richmond northeastward the fronts of the Green Bay and Lake Michigan glaciers were still in conjunction along the line of the interlobate moraine, while the south front of the Green Bay Glacier stood at the outer or Johnstown moraine. In western Kenosha County the west front of the main Lake Michigan Glacier still occupied the morainal belt west of Fox River, though the angle of junction with the south front of the Delavan lobe was shifted northward to a position not far from the southwest corner of Racine County. The distribution of these moraines is shown in Pl. IV.

DARIEN TERMINAL MORAINE.

The principal terminal moraine of the Delavan lobe is the Darien moraine, so designated from the fact that the village of Darien in western Walworth County stands on the outer margin of the moraine near the most southwesterly point reached by the Delavan lobe. The distribution of this moraine is shown on Pl. IV.

This moraine varies in width from 1 to 3½ miles, its slopes usually presenting very moderate relief. Between Richmond and a point opposite the head of Delavan Lake this relief is but 20 to 40 feet, except where erosion of the bordering outwash deposit has increased it to 60 feet. Near the village of Walworth it reaches 100 feet, and south of Lake Geneva the long slope rises 100 to 150 feet above the low area at the south. From Lake Geneva to its junction with the Valparaiso morainal system, south of Burlington, there is no regular outer slope, but the deposit is largely broken by irregular, winding, marshy depressions, from which the immediate slopes rise 20 to 80 feet.

The relief of the inner slope is even more variable. Where bordered by Turtle Creek the relief of 60 to 110 feet is in part due to the subsequent deepening of this valley. From Delavan to Lake Geneva, excepting the Delavan Lake basin and small eroded valleys on the north and south, there is no definite

inner slope and but 20 to 60 feet relief. At several places the terminal-moraine topography passes almost imperceptibly into that of the ground moraine. The bed of Delavan Lake lies 140 to 150 feet below the higher points opposite its head. By far the greatest relief is found in the slopes of the Lake Geneva basin. In the western part, between Cooks Camp and Camp Collie, the lake reaches its greatest depth, 142 feet. The elevation of the bottom here is 719 feet above the sea. This is 400 feet lower than the morainal crest 1½ miles southeast. Between the foot of the lake and Burlington the inner margin of the moraine has, in part, a somewhat regular front, but elsewhere it is very irregular. Here the higher parts are near the inner margin, and abrupt reliefs of 40 to 120 feet occur. Much of the irregularity of this inner margin occurs at the junction of the Elkhorn and Darien moraines.

From Richmond to Lake Geneva the prevailing surface contours are of the sag-and-swell type. The reliefs are very gentle in the inner part of the belt, but become somewhat stronger near the outer front. Some parts of the outer half are closely pitted with kettles 10 to 40 feet in depth, and gravel knolls 15 to 40 feet in height occur. South of Lake Geneva some slight kettles are found, but for the most part the surface of the bulky ridge is marked by gentle undulations. From Lake Geneva to Burlington the topography is much more diversified. The morainal belt is interrupted by very irregular, marshy depressions with abrupt surrounding slopes. The inner part of the belt has quite generally a strongly marked knob-and-kettle topography, where humps and hollows are closely crowded and 30° slopes and abrupt reliefs of 40 to 100 feet are not infrequent. Here and there are small basins, utilized as fields, surrounded by abrupt winding ridges of gravel. Eastward across the moraine the topography becomes more subdued, the relief decreases, and, except about the margins of the marshy depressions, the knobs and kettles give place to sags and swells and gentle undulations. The irregular depressions unite to form two continuous valleys, which lead from the marshes along White River within the moraine to the marshy valley of Nippersink Creek within the Geneva moraine, and thence to the outlet through the latter moraine at Genoa Junction.

At the head of the Geneva basin there is a sag in the Darien moraine, at an elevation of 1,000 feet, or 140 feet above the level of the lake, but neither the sag nor the surface of the outwash plain gives evidence of the passage of much water outward from the lake basin. Two miles north of the village of Darien the moraine is cut by a broad valley, which varies in width from one-half mile to 1½ miles. Its broad, flat bottom, through which winds Turtle Creek, lies 80 to 100 feet below the adjacent higher parts of the moraine. This valley, which will be referred to as the Turtle outlet, was eroded by glacial waters subsequent

to the withdrawal of the ice from this moraine. Kettle holes occurring in the north slope to within 40 or 50 feet of the valley bottom indicate the existence of a sag in the moraine at this point which doubtless determined the location of the valley.

Judging from the surface exposures and the well records obtained, this morainal belt is mostly composed of sand and gravel. A well in the ridge south of Lake Geneva is 329 feet deep; of this at least 300 feet is in blue-clay till. A considerable part of the bulky deposit may have been formed at an earlier stage of glaciation.

JOHNSTOWN TERMINAL MORAINE.

Extending westward from the vicinity of Richmond, near which point the fronts of the Delavan lobe and the Green Bay Glacier diverged, is the Johnstown terminal moraine of the Green Bay Glacier. This moraine is so designated because the villages of Johnstown and Johnstown Center, in eastern Rock County, are situated near the most southerly points reached by the ice at this stage. The width of this moraine varies from three-fourths of a mile near Richmond to nearly 5 miles farther west.

Bordering this moraine on the south is an extensive outwash plain, from which the front of the moraine rises rapidly in places, but generally with gentle slope, 40 to 140 feet, to the undulating crest line, which varies in altitude between 920 to 1,060 feet above the sea. In general the inner and outer slopes are much the same, but on entering Walworth County from the west, as the interlobate angle is approached, the moraine narrows and the inner face becomes abrupt and high.

In its surface contours this morainic belt is somewhat variable. Considerable areas of the inner half of the moraine have the gentle undulations of the ground moraine, with slight sags and swells here and there. The surface is generally rougher in the outer half, where gravel knolls and kettles frequently occur. In general the surface contours of both the Johnstown and Darien moraines are much the same. More or less ice was buried in the morainal drift, as is evinced by the sags and kettles, yet the intricate topography of the interlobate moraine is not to be found. This difference between the topography of the frontal and that of the interlobate moraines is general throughout the area and may be, in part at least, the result of the difference in the conditions under which the ice melted. Along the frontal margins when the ice melted the water flowed immediately away from the ice front in separate streamlets, washing the gravels as it went, so that there was less chance of burial of ice masses before they were melted. Between the contiguous ice slopes of an interlobate tract the water of the two glaciers united to form a considerable stream, which flowed along the intervening

trough, washing the gravels over frequent and considerable masses of ice before they had time to melt. In the interlobate tracts there was doubtless considerable pushing up of morainal material into an intricate series of heaps and ridges as the result of forward crowding of the contiguous ice fronts after intervals during which they had been melted back slightly in certain parts. Along the frontal margins such oscillations would probably be of the nature of overriding rather than of plowing up or pushing up.

The surface exposures of this moraine are very largely of till, but the records of the wells indicate that the great bulk is of sand and gravel. Fifteen wells ranging in depth from 120 to 238 feet, concerning which information was obtained, were reported as almost entirely in sand and gravel after penetrating the superficial coating of till.

Where the Johnstown moraine crossed the pre-Glacial Rock Valley southwest of Milton Junction, the crest lowers and a notable break occurs, forming the sag which is traversed by the Chicago and Northwestern Railway. This break is not wholly, at least, due to erosion, since its bottom is marked by inclosed depressions, the largest of which extends 100 feet below the level of the bordering outwash plain.

About 5 miles farther west, where the moraine crosses the pre-Glacial Catfish or Yahara Valley, the present Rock River has cut its channel. Two narrow breaks in the morainal crest near Richmond appear to have afforded temporary outlets for the water ponded behind the moraine after the withdrawal of the ice from the crest.

INTERLOBATE DEPOSITS.

For nearly 7 miles northeastward from the village of Richmond the Darien and Johnstown moraines are combined into an interlobate deposit varying in width from 1¼ to 3 miles. Beyond this the Kettle moraine consists of one indivisible moraine extending northeastward, which bears the impress of a later stage, though it is probable that the deposition of the constituent material was begun while the Darien and Johnstown moraines were being formed.

On the west side of this interlobate tract the slope rises abruptly from the depressions in which lie Number 9, Whitewater, and Bass lakes to heights of 60 to 140 feet. This slope is the ice-contact face of the Johnstown moraine. There is generally a well-defined crest broken by kettles, gravel knolls, and ridges. There has been considerable subsequent filling behind the Darien moraine, but the eastern crest still stands 40 to 60 feet above the plain on the east. Farther south, where there has been less filling, there is an abrupt ice-contact face of 80 to 120 feet relief. The crest on this side, which is also pitted with depressions, marks the Darien moraine.

Near Richmond the Johnstown crest is the higher of the two, but farther north this crest lowers somewhat and the Darien crest gains the ascendency. From the latter a flat resembling an outwash apron declines gently to the west to about the level of the western crest, but does not cross it. Near Richmond the gravel filling between the two crests is less uniform, being broken by sags and swells and some large depressions, so that it has more the appearance of a continuous morainal deposit than an outwash from either side.

Cutting across this interlobate tract is an eroded channel 20 feet or more in depth, which was probably developed at a subsequent stage as an outlet for glacial waters.

The fact that the ice-contact face of each morainal member of this belt is clearly and, for the most part, even abruptly defined, and that there is no indication that outwash from either moraine was carried across to the inner side of the other moraine, shows conclusively that the ice fronts were contemporaneous in their occupancy of the Darien and Johnstown moraines. There is here no indication of a difference in the vigor of the glaciers, though before the withdrawal from the interlobate tract the south front of the Darien glacier appears to have withdrawn from the Genoa moraine.

Along the trough between the contiguous frontal slopes of the two glaciers doubtless much water collected, and a vigorous flow set in toward the point where the ice fronts diverged. A large part of the interlobate morainal drift was assorted by this drainage, and much of the finer material was carried on and commingled with that being washed out directly from the ice fronts along the Darien and Johnstown moraines.

In this interlobate tract conditions were favorable for the burial of masses of ice, and, as a consequence, abundant kettles, some of large size, occur. Two miles northwest of the village of Heart Prairie there is an especially intricate topography of abrupt winding gravel ridges and depressions, of which the angle of slope frequently exceeds 30°. Between the crests of the ridges and the bottoms of the immediately adjacent hollows reliefs of 60 to 100 feet occur.

The material exposed is mostly well rounded and ranges in size from coarse sand to cobblestones 8 to 12 inches in diameter. Some larger stones occur. The gravel deposit is usually covered with a coating of clay, except on the steeper crests and slopes, where it outcrops through the thin soil. Two wells in the higher parts of this tract are said to reach the rock at depths of 255 and 236 feet. The material penetrated by the wells is principally sand and gravel, with occasional layers of blue clay. In places hard blue clay is reached below the assorted material.

OUTWASH FROM THE DARIEN AND JOHNSTOWN TERMINAL MORAINES.

While the Delavan and Green Bay ice fronts occupied the outer terminal moraines, very extensive bordering deposits of stratified drift were formed. The distribution of these deposits is shown on Pl. IV, and the relations of these deposits to the pre-Glacial Rock and Troy valleys will be seen by reference to Pl. II. That the discharge of glacial waters at this stage was large in volume and vigorous in its flow is shown by the extent and character of these deposits of gravel and sand. The more sluggish waters of the closing stages spread over the whole a coating of loamy clay varying in thickness from a few inches to 15 or 20 feet, so that few more fertile areas are to be found in this region.

The amount of filling in these pre-Glacial valleys is very considerable. The plain or terrace which forms the surface of this deposit has an elevation of 900 feet above the sea at the front of the moraine north of Janesville. Here there must be at least 450 feet of filling. The terrace declines southward, so that at the State line, 16 miles away, it has lowered 100 to 120 feet, and here there is probably at least 300 to 350 feet of filling.

Big Foot Prairie, at the front of the moraine near Walworth, has an elevation of 1,000 feet above the sea. If the projection of Troy Valley is correct there must be at least 500 feet of filling here outside the moraine.

Where till or "hardpan" occurs below the sand and gravel, this till is probably to be referred to an earlier stage of glaciation, but where little else than sand and gravel occurs there is no means of determining how much of the filling was deposited during the stage under discussion and how much belongs to an earlier stage, even where deep wells penetrate the deposit. There was undoubtedly an earlier glacial filling and probably considerable inter-Glacial erosion. Of 140 wells on the outwash plains, concerning which information was obtained, 114 penetrated only sand and gravel below the superficial coating of clay. Numerous other wells penetrated beds of clay or "hardpan," especially in the lower part of the section.

The tributary of the pre-Glacial Rock Valley south of the moraine, in eastern Rock County, shallows rapidly to the eastward, so that over the divide southeast of the village of Johnstown Center there is but 35 to 40 feet of gravel.

From the village of Richmond to a point about 4 miles southeast of the village of Darien such of the waters from the front of the Delavan lobe as did not cross the divide to the west found their way to Rock River by the valley of Turtle Creek. That the flow through this valley was vigorous is shown by the extensive deposit of coarse gravel leading into this valley, and by the like deposit extending from the foot of the rock gorge north of Clinton Junction to Rock River. That a considerable part of the gravels between this gorge and

the State line were really washed through this Turtle Valley is clearly shown by the following facts: First, the surface of the deposit declines westward from the foot of the gorge; second, the gravels are coarser where the eastern contribution comes in, and thence southward, than north of this junction; and third, most of the exposures, especially in the eastern part of the deposit, show higher percentages of Niagara limestone than those north of this junction, thus indicating drift of easterly derivation.

The character of these gravels where cut by the Chicago, Milwaukee and St. Paul Railway, 2½ miles northwest of Allens Grove, is shown in Pl. VII, *B*. Between the Darien moraine and the Turtle Creek rock gorge very extensive erosion of these gravels took place during the subsequent recession of the glacier. An extensive lower plain was developed by the erosion of 20 to 30 feet, and in this lower terrace was cut, still later, the channel, about 20 feet in depth and 80 rods in width, whose bottom forms the present flood plain of Turtle Creek. A second channel cut in these gravels joins Turtle Valley from the north, so that only the highest terrace in the area west of Darien is to be correlated with the formation of the Darien moraine. Besides the present valleys of Rock River and Turtle Creek, this terrace is trenched to a limited extent by tributary ravines.

The outflow from the ice fronts must have been vigorous to have handled so much coarse material, though it is possible that floating ice may have assisted in transporting the larger stones. Within 2 to 3 miles of the Johnstown moraine a large part of the material exposed is of pebbles 3 to 6 inches in diameter. At the Chicago, Milwaukee and St. Paul Railway gravel pit, in the north part of Janesville, a large part of the pebbles reach 4 inches and not a few are 8 and 10 inches in diameter. Some stones of this size are seen 7 miles from the moraine. From the south part of Janesville to the latitude of Afton the great bulk of the material is coarse sand and gravel less than 2 inches in diameter.

From that part where the outwash from the Darien moraine comes in from the Turtle outlet southward to the State line there is more coarse material as a consequence of the increased volume of water. With the finer material there is very much gravel ranging from 4 to 10 inches in diameter.

Considering the volume of this discharge, the fact that no outwash crossed to the low areas behind either the Johnstown or the Darien moraine in the interlobate tract northeast of Richmond appears to be conclusive proof that the Green Bay Glacier and the Delavan glacial lobe withdrew simultaneously from these moraines. On the other hand, the relations of the morainal and outwash deposits south of Burlington leave little ground for doubt as to the contempora-

neous occupancy of the Darien moraine and the Valparaiso moraine by the converging fronts of the Delavan lobe and the main Lake Michigan Glacier, respectively. The Johnstown, Darien, and Valparaiso moraines were thus contemporaneous in origin, while Marengo Ridge and the composite morainal belt on the east are of earlier age, probably having been deposited during an earlier advance of the Wisconsin stage.

The glacial drainage from the ice fronts in southwestern Kenosha County and southeastern Walworth County escaped by the Nippersink outlet through the Genoa moraine at Genoa Junction. From this time until the ice had almost entirely disappeared from Walworth County and southwestern Waukesha County this Nippersink outlet was an important factor in the development of the area. In this tract between the Darien and Genoa moraines the very gently undulating ground moraine tracts and those underlain by outwash gravels have not been very satisfactorily distinguished.

DEGLACIATION OF THE AREA.

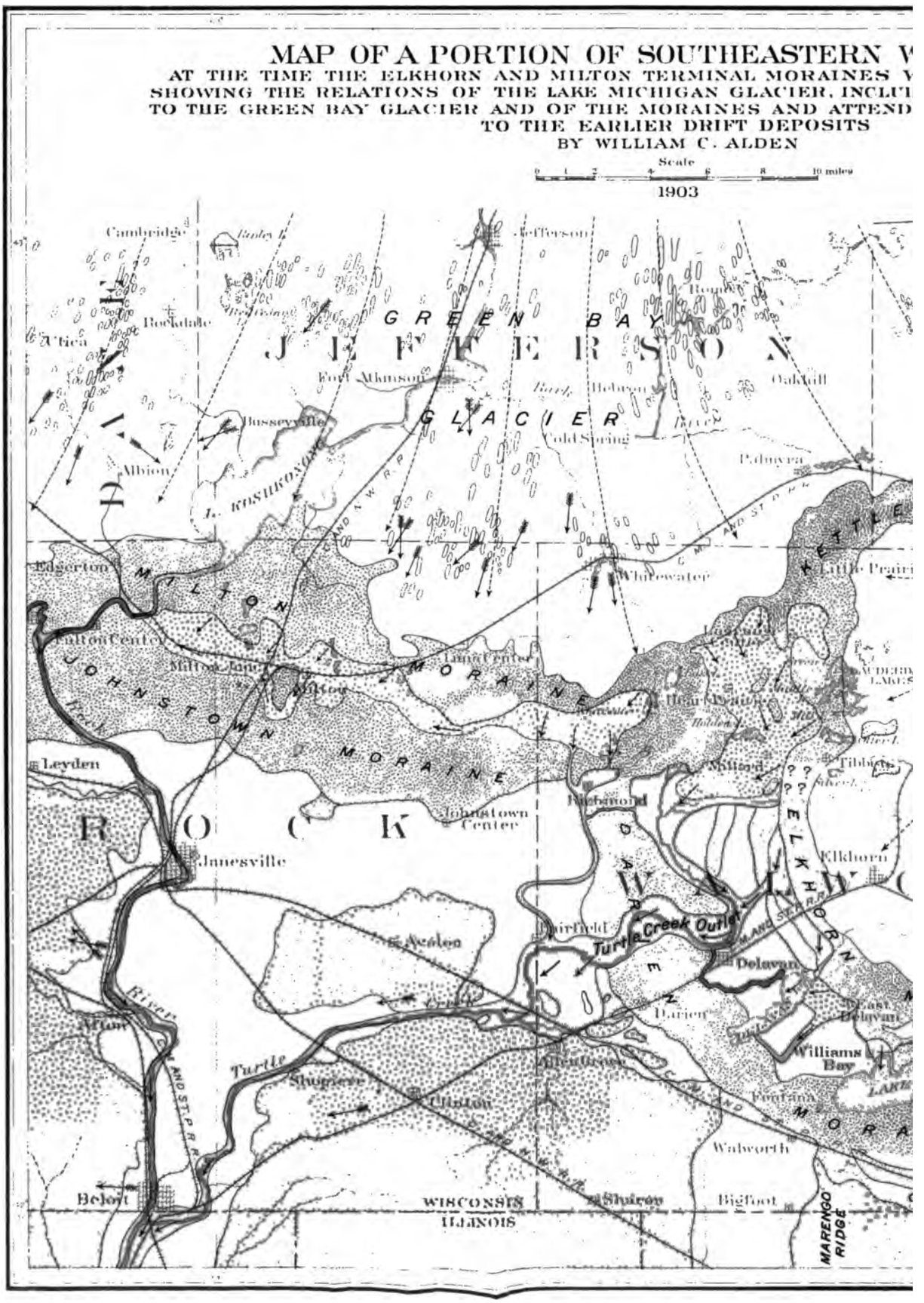
GENERAL RELATIONS.

The process of deglaciation of the area appears to have begun with the melting back of the south front of the Delavan lobe from the Genoa moraine, but the retreat of the ice fronts did not become general until the completion of the Darien and Johnstown moraines. When this was accomplished the front of the Green Bay Glacier withdrew from the Johnstown moraine, and that of the Delavan lobe abandoned the Darien moraine. Whether there was a considerable retreat followed by a readvance to the position of the inner moraines, or whether the intervals of a few miles between the inner and outer moraines mark the full extent of the wasting of the glaciers at this time, is not known.

During the several stages in the deglaciation of the area the glacial waters played a very important part in the development of the phenomena of this area, and in this process the determining factors were the relations of the ice fronts of the Green Bay and Delavan glacial lobes and the successive opening of lower and still lower outlets for the glacial drainage.

ELKHORN TERMINAL MORAINE.

If the melting back of the south front of the Delavan lobe from the Genoa moraine to the Darien moraine be regarded as the first stage in the deglaciation of the area under discussion, the close of the second stage would be indicated by the formation of the Elkhorn moraine of the Delavan lobe and the Milton moraine of the Green Bay Glacier. The distribution of these moraines and


MAP OF A PORTION OF SOUTHEASTERN W
AT THE TIME THE ELKHORN AND MILTON TERMINAL MORAINES W
SHOWING THE RELATIONS OF THE LAKE MICHIGAN GLACIER, INCLU
TO THE GREEN BAY GLACIER AND OF THE MORAINES AND ATTEND
TO THE EARLIER DRIFT DEPOSITS
BY WILLIAM C. ALDEN
Scale
1903
GREEN BAY
GLACIER
MILTON
MORAINE
JOHNSTOWN
MORAINE
ELKHORN
MORAINE
ROCK
RIVER
Turtle Creek Outlet
Cambridge
Rockdale
Attica
Fort Atkinson
Jefferson
Oakhill
Cold Spring
Palmyra
Albion
Bussey ville
Edgerton
Whitewater
Little Prairie
Milton Center
Milton Junction
Milton
Lima Center
Leyden
Johnstown Center
Janesville
Richmond
Milford
Fibbets
Elkhorn
Fairfield
Delavan
Darien
East Delavan
Williams Bay
Lake Geneva
Fontana
Walworth
Turtle
Shopiere
Clinton
Beloit
Sharon
Bigfoot
WISCONSIN
ILLINOIS
MARENGO RIDGE

IN
G FORMED
ELAVAN LOBE,
SH DEPOSITS
North Milwaukee
Elm Grove
Wauwatosa
C. M. AND ST. P. R. R.
Wales
Waukesha
North Greenfield
C. AND N. W. R. R. MILWAUKEE AND MADISON LINE
New Berlin
Genesee Depot
Sayles ville
Prospect
Oakes Corners
North Prairie
Tess Corners
Little Muskego L.
Muskego
St. Martin
Jericho Corners
Big Bend
Muskego
Eagleville
Mukwonago
Durham
Oakwood
DELAVAN
Caldwell
Lake Beulah
Tichigan L.
Wind L.
East Troy
North Cape
Thompsonville
Waterford
LOBE
Honey Creek
Rochester
Yorkville
Vienna
Long L.
Eagle L.
Browns L.
Dover
C. M. AND ST. P. R. R.
Ransasville
Union Grove
Sylvania
Burlington
Lyons
Pleasant Prairie
Fox River
Pishtaka
Sharps Corners
Andalusia L.
Hooker L.
Bristol
C. AND N. W. R. R.
Silver Lake
Salem
Montgomery L.
Camp Lake
George L.
Trevor
Wilmot
Twin Lakes
Grand Dune
Richmond
English Prairie
Antioch
BOUNDARY LINE
MORAINE
VALPARAISO
MICHIGAN
GLACIAL
LAKE
RACINE
GLACIER

the relations of the ice fronts are shown on Pl. V. A slight intermediate morainal belt lies east and northeast of Delavan.

The Elkhorn terminal moraine, which lies 3 or 4 miles within the Darien moraine, takes its name from the fact that it passes just west of the city of Elkhorn. This moraine varies in width from one-half mile to 2 miles, with a relief of 20 to 60 feet. Crossing the valley of Jackson Creek the moraine rises to the elevated tract where, as previously noted, it crosses what appears to be the northward extension of the Marengo Ridge. A belt of gravel knolls and kettle holes descends from this elevated tract, crosses the sag between the heads of Lake Como and Williams Bay, and can be traced for 2 miles along the northern slope and crest of the ridge separating the two lake basins. A belt of similar morainal character extends eastward from the same elevated tract along the slope forming the north side of the Lake Como basin. Morainal characters are also shown by the bulky ridges running thence northeastward toward the village of Lyons. Interrupted areas of knob-and-kettle topography connect this belt with the inner part of the Darien moraine. Near the Racine County line the moraine swings northward toward Burlington. Here the knob-and-kettle topography is very strongly developed.

The west front of the Lake Michigan Glacier still occupied the morainal belt west of Fox River, and the junction of the two ice fronts formed a reentrant angle, near the apex of which stands the city of Burlington. The conditions of deposition in this interlobate angle were peculiarly favorable to the burial of masses of ice in the morainal and outwash débris, so that an area of very rough topography was produced. In the western half of this interlobate tract there is a bulky morainal deposit a mile or more in width, with a relief of 50 to 120 feet above the White River bottom on the west. In the eastern half the deposit is much weaker and is interrupted by marshy depressions. This difference in strength may be an indication that by this time the vigor of the main glacier was beginning to wane.

A marshy depression between these two parts connects with a similar valley along the south front of the Darien moraine. This channel, and two irregular breaks in the Darien moraine between Burlington and Geneva, allowed the glacial waters to escape to the Nippersink outlet at Genoa Junction.

The bulky ridge between Springfield and White River, and between Lake Geneva and Lake Como, is very largely of till. In places the morainal features have the appearance of being superposed on a preexisting drift ridge. As in the case of the ridge south of Lake Geneva, it is not improbable that the drift of these ridges may, in large part, have been deposited during an earlier glacial stage.

A well near the crest of the ridge, about 2 miles east of this exposure and 1 mile west of Geneva, was said by the driller, Mr. John Miller, of Genoa Junction, to have penetrated 317 feet of clay over the limestone. Frequent exposures along the crests and slopes of these ridges, however, show gravel. Pl. VI, *A*, shows the character of much of this morainal material. It ranges from fine gravel and coarse sand to small bowlders a foot or more in diameter, and, as elsewhere, 80 to 90 per cent of this is limestone. In some exposures the finer material is stratified and cross bedded, but usually there is little more definite bedding than can be seen in the illustration. The pebbles are generally well rounded and rarely show the striated facets seen on the stones in the till. The gravel deposits are generally coated with clay and humus, but on the more abrupt knolls and steeper slopes the soil is very thin.

The point of junction of the fronts of the Delavan lobe and Green Bay Glacier at this stage was removed to the vicinity of Lagrange Center, a position about 9 miles northeast of its former location. This position allowed the outwash from a frontage of 3 miles of the Green Bay Glacier to be discharged into the low area behind the Darien moraine, where it commingled with that from the Delavan lobe and built up the deposit of sand and gravel underlying Heart Prairie. On the further withdrawal of the Delavan ice front that part of the area behind the Elkhorn moraine which lies between the Kettle moraine and Sugar Creek Valley was filled with outwash, which so far buried the Elkhorn morainal deposits that only the higher parts rise above the outwash plain and can be distinguished therefrom. There is thus a measure of uncertainty in the statement that the junction of the ice fronts at this stage was in the vicinity of Lagrange Center. As will be noted from the description of the conditions, however, this uncertainty is not great. Near Lagrange Center the gravel plain between the Darien and Elkhorn moraines is slightly higher than the outwash deposits to the east, and the two tracts where not separated by higher morainal deposits are separated by a narrow channel leading southward from Lagrange. This appears to have been developed by the southward flow of the water after the Delavan ice front had withdrawn somewhat to the eastward. Farther south, where the latter plain is lower, the channel cuts across it between the villages of Millard and Tibbett.

Besides their greater elevation, the higher morainal tracts are distinguished from the surrounding outwash by the undulating surfaces, by the occurrence of till, and by the occurrence of bowlders on their surfaces. Bowlders are absent from the surrounding outwash plain. The burial of the great masses of ice, whose subsequent melting formed the basins of Otter, Lauderdale, and Pleasant lakes, occurred at this time.

A. SECTION OF A KAME 1 MILE NORTH OF BURLINGTON, WIS., SHOWING THE POOR ASSORTMENT AND THE WATERWORN CHARACTER OF THE MATERIAL.

B. OUTWASH GRAVELS OVERLYING GALENA LIMESTONE AT THE HEAD OF THE TURTLE CREEK ROCK GORGE AT CARVERS ROCK, 3½ MILES NORTHEAST OF CLINTON JUNCTION, WIS.

MILTON TERMINAL MORAINE.

It has already been shown how, at the west, the Green Bay Glacier spread out 40 to 60 miles from the main axis of the movement. On the south, also, the deployment of the ice was unrestricted. On the east, however, the glacier did not reach the full limit of its power to advance, but was stopped midway in its extension by the opposing front of the Lake Michigan Glacier. When the melting of the Green Bay Glacier began, it would be expected that the first withdrawal from the outer terminal moraine would be on the south and west, while the east front continued pressed against the interlobate moraine. This appears to be just what happened.

Lying within the Johnstown moraine, nearly parallel to it and separated from its inner border by a space averaging about 2 miles in width, is an inner morainal belt marking the first stage in the retreat of this glacier. From its strong development in the town of Milton, and its relation to the villages of Milton and Milton Junction, this moraine may be conveniently referred to as the Milton moraine. The distribution of this moraine and the accompanying gravel terrace is shown on Pl. V. Its formation appears to have been contemporaneous with the Elkhorn moraine of the Delavan lobe.

That part of the Kettle moraine extending from the junction with the Elkhorn moraine, near Lagrange Center, southwestward to a point about 1 mile north of Bass Lake, though doubtless begun as an interlobate moraine while the Darien and Johnstown moraines were being formed, was completed as a part of the Milton terminal moraine. This is shown by the relations of the gravel terrace bordering it on the south. North of Bass Lake this moraine joins a complicated morainal tract at the north end of the interlobate deposit described as resulting from the coalescence of the Darien and Johnstown moraines (Pl. XI). Lying across the north end of this interlobate tract, the Milton moraine continues, with two narrow breaks, to the point of its distinct separation from the earlier moraines. North of Bass Lake the moraine is composed of a single bulky ridge with nearly 150 feet of relief on the south. This great relief appears to be due to the fact that the continuance of very considerable masses of ice in the angle between the Johnstown and the Milton moraines prevented the filling of the area with outwash. Pl. VIII, *B*, gives glimpses of the knobs and ridges of gravel surrounded by low marshy tracts in this angle behind the Johnstown moraine. In northwestern Walworth County the moraine is narrow and ridge-like, with an abrupt ice-contact face, rising 80 to 200 feet above the marshes. The crest and slopes are generally pitted with kettle holes and the outer front, except in the vicinity of Bass and Whitewater

lakes, is bordered by an outwash apron, above which the undulating crest of the moraine rises 15 to 60 feet.

Westward to Rock River, in northeastern Rock County, the moraine is broader and less abrupt. From a narrow ridge it spreads out in a belt varying from 1 to 3 miles in width. It is marked here and there by sharply knobbed and pitted areas, but for the most part the topography is one of gentle sags and swells, with inclosed marshy depressions. Where the moraine crosses the pre-Glacial Rock Valley the irregular surface indicates the burial of very much ice. A notably large depression is that in which lies Clear Lake, 1½ miles northwest of Milton Junction. This has a length of nearly 2½ miles, a breadth varying from 40 rods to one-half mile, and a depth of 60 feet or more.

Immediately north of this moraine lies the basin of Lake Koshkonong, which is due to the damming of the pre-Glacial valley by the morainal deposits.

TERRACES OF OUTWASH SAND AND GRAVEL ASSOCIATED WITH THE FORMATION OF THE ELKHORN AND MILTON MORAINES.

In general, less extensive deposits of outwash material were associated with the formation of the Elkhorn and Milton moraines than border the outer terminal moraines. These deposits were limited to a large extent by the inner slopes of the outer moraines. Beyond these limits the glacial waters accomplished considerable erosion.

As has already been shown, the point of junction of the fronts of the Delavan lobe and the Green Bay Glacier was removed to the vicinity of Lagrange Center when the Elkhorn moraine was being formed, a position about 9 miles northeast of Richmond, its location at the previous stage. This position allowed the gravel-bearing water from a frontage of 3 miles on the Green Bay Glacier to be discharged into the low area behind the Darien moraine, where it commingled with that from the Delavan lobe. This outflow was unrestricted and vigorous, so that the intermorainal area received a filling of sand and gravel, which extends as far south as the valley occupied by the heads of Sugar and Turtle creeks, a distance of 6 to 7 miles from the Milton moraine. As in the other outwash aprons, the sand and gravel is generally coated with a few feet of clay and prairie loam. On this terrace stands the village of Heart Prairie.

At the front of the Milton moraine this terrace has an elevation of 980 feet above sea level. The higher parts of the narrow, broken, ridge-like crest of the moraine rise 40 to 60 feet above it. From the elevation of 980 feet at the moraine the terrace declines to an elevation of 910 to 920 feet at Turtle Creek Valley. Excepting two slightly elevated tracts of drift deposited by the Delavan glacial lobe which are surrounded by outwash material, and the depression occu-

pied by Holden Lake, in which a great mass of ice must have been buried, this plain is nearly as flat as a floor, the uniformity being broken only by occasional slight sags.

The disposition of the deposit indicates that the outwash was principally from the Green Bay Glacier. The percentages of Niagara limestone, shown in Table F (p. 93), are intermediate between the low percentages of Niagara material in the Milton moraine and the high percentages of material from the same formation in the Elkhorn moraine, so that more or less mixing probably occurred in the discharge from the trough between the contiguous ice fronts north of Lagrange Center, even if there was but little outwash from the Elkhorn moraine itself.

Of 17 wells on this terrace and the adjacent moraines, concerning which information was obtained, 5 were reported as reaching limestone at depths ranging from 200 to 235 feet. The deposits penetrated by three of the deeper wells were stated by the owners to be as follows:

Log of George MacDougal well in SW. ¼ sec. 29, Lagrange Township.

	Feet.
Clay	3 to 5
Coarse gravel	70
Sand	125
Limestone at depth of 200 feet.	

Log of J. W. Duncan well in SW. ¼ sec. 33, Lagrange Township.

	Feet.
Drift, probably gravel	65
Clay	80
Quicksand	?
Clay	40 to 50
Sand	?
Hard bluish limestone	12
Depth	247

Log of William Sherman well in SE. ¼ sec. 5, Sugar Creek Township.

	Feet.
Clay	Few
Coarse gravel	45 to 50
Sand	50
Hardpan	20
Sand and gravel	100
Depth	222

Two or three wells about 1½ miles northeast of the village of Heart Prairie penetrated about 130 feet, mostly of "hardpan." This is probably till deposited by the Delavan lobe and subsequently buried by outwash material. Most of the wells are in gravel and sand. Besides such material as was washed out from the

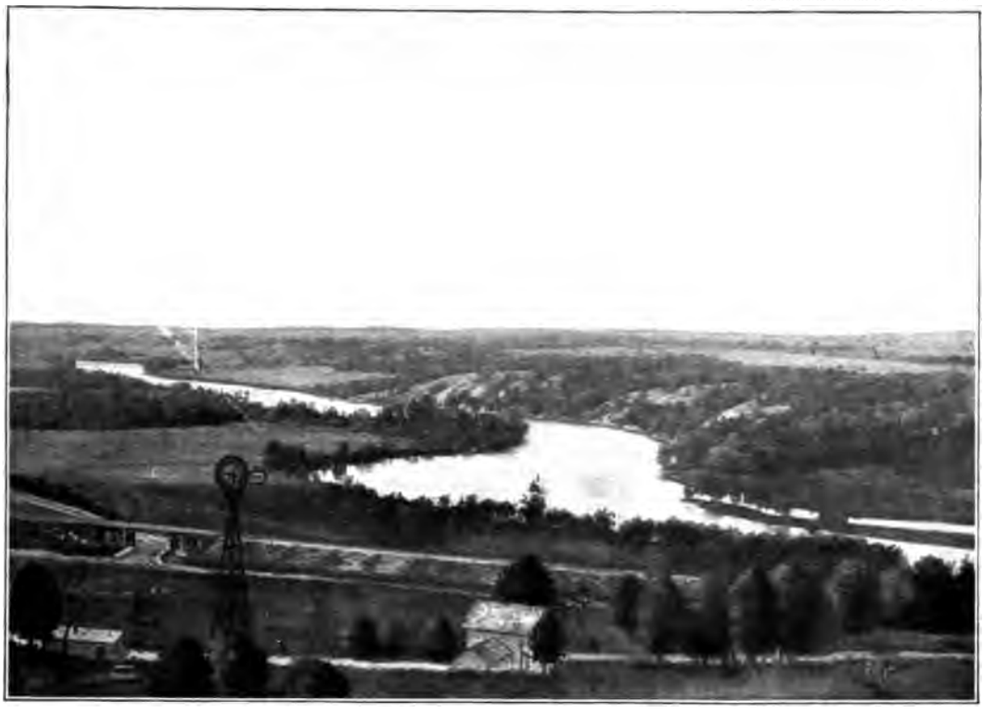
front of the Delavan glacial lobe at this stage and mingled with that from the Green Bay Glacier in forming this deposit, a certain amount of outwash material is found bordering the Elkhorn moraine in the area west of the city of Elkhorn. A like deposit, about 2 square miles in extent, occurs east of Delavan Lake. The gravel terrace at the foot of Lake Geneva, on which the city of Geneva now stands, was probably formed at this time, and a certain amount of material may have been washed into Williams Bay at the same time, though it does not appear that the lake basin received as much filling as might be expected to have occurred.

The interval between the Milton and Johnstown moraines is occupied by an outwash gravel plain varying in width from a few rods to 2 miles (Pl. V). This is well developed in northwestern Walworth County for about 4 miles east of the county line, also to the east of the village of Milton and to the west of the village of Milton Junction. In the first of these tracts the moraine and the outwash are clearly distinct, the morainal crest rising 15 to 40 feet above the plain, which slopes gently away from the moraine. Farther west the morainal front is less distinct from the outwash. In passing from the moraine to the outwash apron in this part the surface lowers and the depressions become less frequent until they disappear almost entirely. The boundary line between the two areas is drawn more or less arbitrarily.

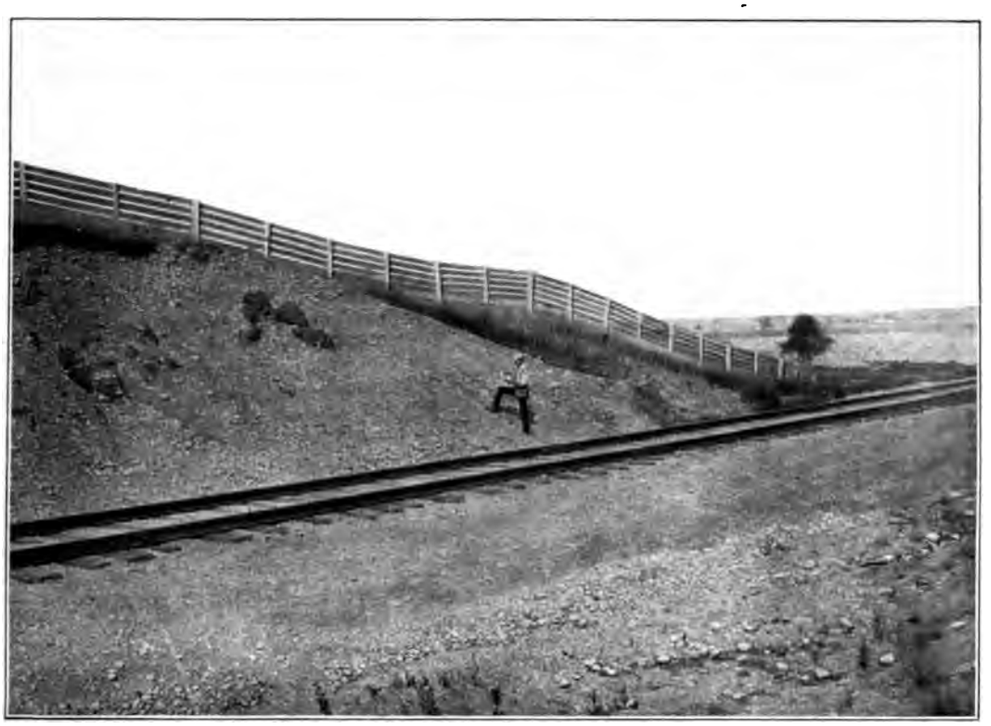
The obstruction to the westward flow of the water ponded between the Milton and Johnstown moraines in the adjacent parts of Walworth and Rock counties caused an overflow through two narrow sags near the village of Richmond. The water thus escaping reached Turtle Creek near Fairfield post-office by the channel leading southward from the village of Richmond, which is cut in the outwash plain. A similar channel across the combined Johnstown and Darien morainal deposits between Whitewater and Holden lakes, southwest of the village of Heart Prairie, allowed some of the water to escape to the low area east of the Darien moraine.

ROCK RIVER.

When the formation of the Johnstown moraine was nearly completed, it is probable that the outflow began to concentrate itself along the west side of the outwash plain and to develop the channel of the present Rock River. As the ice withdrew from the Johnstown moraine the waters ponded behind the morainal crest and found an outlet through a sag where the moraine crosses the pre-Glacial Yahara or Catfish Valley, so that while the Johnstown moraine was being formed the river headed north of the Johnstown moraine. Rock River became the outlet for all the waters discharged into the tract between the moraines from a point 4 miles southeast of Whitewater to the middle of the southern part of Dane County, a glacial frontage of more than 45 miles. The relative elevations of the various



A. THE VALLEY OF ROCK RIVER 2½ MILES NORTH OF JANESVILLE, WIS.; LOOKING NORTH.



B. VIEW AT A POINT 2½ MILES NORTHWEST OF THE VILLAGE OF ALLENS GROVE, WIS., WHERE THE CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY PASSES FROM THE UPPER TO THE LOWER OUTWASH TERRACE.

sags in the crest of the Johnstown moraine show that the initial elevation of the sag where the discharge located itself was not more than 850 feet above sea level. The present elevation of the bottom of the channel at the front of the Johnstown moraine is about 750 feet above the sea. But very little of this water appears to have gone through the sag southwest of Milton Junction, though the elevation now is but 900 feet above the sea. The outwash plain opposite this sag is but very little eroded.

The character of the valley of Rock River north of Janesville is shown in Pl. VII, *A*. The moraine is dimly seen in the distance; on the right the gravel bank rises steeply 150 feet from the water's edge to the level of the outwash plain. A short distance below the bend shown in Pl. VII, *A*, after cutting through the outwash gravels, the river encountered a ridge of limestone over sandstone. The same thing occurred at two points below Janesville, as will be seen by reference to Pl. II. This was due to the fact that the new stream, instead of following the axis of the pre-Glacial valley, chose a course close to the west side of the outwash plain. In eroding its channel the stream was superimposed on salients of the rock slope at several points. Later, when the ice front withdrew from the Milton moraine and the stream extended itself across the divide between the pre-Glacial Yahara, or Catfish, and Rock River valleys, as the outlet of Lake Koshkonong, it was forced to cut its channel in rock for a mile or more above Fulton Center. It also encountered the rock at a point 2 miles east of Edgerton, near the Newville bridge.

TURTLE CREEK OUTLET.

The disposition of the glacial waters discharging into the area behind the Darien moraine at the time the Elkhorn and Milton moraines were being formed led to the development of an outlet through the Darien moraine and the erosion of a large amount of the gravels previously deposited outside.

When the front of the glacier was melted back from the crest of the Darien moraine, in the western part of Walworth County, the glacial waters, ponded between the morainal crest and the retreating ice front, found an outlet through a sag at a point west of the city of Delavan. That there was an initial sag in the crest of the moraine at this place appears from the fact that kettle holes occur in the north slope of the valley at one place down to within 40 or 50 feet of the bottom of the valley, showing that not all of the slope was due to erosion. This sag was deepened and widened by the outflow until a valley varying in width from one-half mile to 1½ miles was developed. This valley is now traversed by Turtle Creek, so that it may be conveniently referred to as the Turtle Creek outlet. From the time of the withdrawal of the ice front

from the Darien moraine until the opening of Sugar Creek Valley this outlet was of great importance. From the crest of the ridge northwest of Williams Bay to the southwestern part of Waukesha County, a frontage of nearly 20 miles on the Delavan Glacier, most of the water from the melting ice went through this outlet. When the Elkhorn moraine was passed a part of this flow was diverted southward to the valleys between Lake Geneva and Burlington, and thence to the Nippersink outlet at Genoa Junction.

In addition to the flow directly from the frontage of the Delavan glacial lobe, that part of the Green Bay glacial drainage which was forming the terrace on which the village of Heart Prairie stands escaped to this outlet after depositing its load. The interlobate drainage from the two glaciers for an undetermined distance to the northeast also made a large contribution until the Green Bay front withdrew from the interlobate moraine. It is possible that even after this withdrawal a certain amount of water from this glacier, ponded between the retreating ice front and the moraine, found egress eastward across the morainal crest through some of the numerous sags, and joined the flow to the Turtle outlet.

After passing the Darien moraine by this outlet the waters found their way across the bordering outwash plain, and, as at the time when the Darien moraine was being formed, followed the present course of Turtle Creek through the rock gorge northeast of Clinton Junction and thence to Rock River.

For about 2 miles, where Turtle Creek cuts through the pre-Wisconsin drift area in eastern Rock County, the present valley is constricted. In this part the stream is bordered by a flood plain 20 to 40 rods in width, from which the side slopes rise to heights of 80 to 100 feet, the lower 60 or 70 feet of which is cut in Galena limestone. On the north side the rock is exposed in vertical bluffs. The south side is less abrupt. At the east and west ends of this gorge the limestone is overlain with outwash gravels (Pl. VI, *B*). At the east end these gravels reach a level 60 to 65 feet above the present stream. It is probable that this rock gorge marks the position of a col at the head of the broad pre-Glacial valley which opens out to the westward from its foot. This col was filled, up to the level of the higher terrace, with gravels washed out from the Darien moraine.

The vigorous outflow from the Turtle Creek outlet after the withdrawal of the ice front from the Darien moraine excavated much of these gravels, and subsequent erosion brought the valley bottom to its present position. It was reported to the writer that piling for the bridge near Winegar's quarry, north of Clinton Junction, was driven 18 feet in the valley bottom without striking rock. This report was not verified, but, if it is correct, it indicates that considerable filling remains in the bottom of the gorge, and that the rock cut can not be

correlated with the development of the Turtle Creek outlet through the Darien moraine.

East of the head of this rock gorge three distinct stages may be traced in the development of the topography now seen. At the first the upper terrace or main gravel plain was formed, as previously described. North of Turtle Creek this has been but little modified by subsequent erosion. South of the creek, to the border of the older drift area, only remnants of these high-level gravels remain. One of these, a terrace varying in width from one-half to 1 mile, borders the moraine front. Parts of this terrace retain the original elevation, but more or less erosion has occurred. Except for these remnants, over an area of nearly 8 square miles, lying mostly south of the creek, these gravels have been removed to a depth of 20 to 50 feet, forming a gently undulating plain that distance below the level of the upper terrace north of the creek. This erosion appears to have been accomplished between the time of the withdrawal of the ice front from the Darien moraine and its subsequent retreat from the Elkhorn moraine. A glimpse of the relations of the upper and lower terraces may be had in Pl. VII, *B*. This view was taken in eastern Rock County, where the Chicago, Milwaukee and St. Paul Railway passes from one terrace to the other.

The top of the cut in the left foreground marks the level of the upper terrace. From this the surface drops down 30 to 40 feet to the right, in a steep erosion slope, to the lower terrace, which is seen in the right background.

The lower terrace continues northeastward as the bottom of the Turtle outlet through the Darien moraine. This terrace, which is now cut by the meandering course of Turtle Creek, reaches an elevation of 940 feet about 1 mile north of the city of Delavan, where it stands 40 feet above the neighboring flood plain of the creek. This is a rise of 60 to 70 feet in 8 or 9 miles from the points shown in Pl. VII, *B*. The surface appears to have been developed by a current that shifted its course as the valley deepened. The incoming of the vigorous flow from the north, behind the Darien moraine, crowded the eroding current against the south side of the valley near Delavan. From here it was deflected sharply to the northwest, then to the southwest. The continued deflections in gradually shifting courses appear to have been the cause of the remarkably extensive erosion in the area west of the Darien morainal front. As the valley north of Delavan deepened, the outflow from the Elkhorn moraine deepened its course, so that, instead of finding a continuance of this lower terrace from the east side of Turtle Creek Valley to the front of the Elkhorn moraine, we find a broad valley heading in the break in the slight intermediate morainal belt northeast of Delavan, through which the Elkhorn waters found egress.

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The waters continued to come to this outlet from the north for a considerable time after the retreat of the ice front from the Elkhorn moraine, until the Sugar Creek outlet was opened. The flow gradually established itself in the broadly sinuous course of the present stream and developed a broad channel whose banks rise 10 to 40 feet to the variable surface of the lower terrace on either hand. To the east and south of Fairfield post-office the bank rises 60 feet from the flood plain of the creek to the upper terrace.

Before the Turtle Creek outlet was fully opened there appears to have been more or less of a discharge through the narrow breaks in the crest of the Darien moraine about 1 mile southeast of the village of Richmond. This was joined by a flow from the Green Bay Glacier through two narrow sags near the same village. The stream formed by the confluence of these outflows flowed southward for 2 miles close to the morainal front, where it eroded a channel 40 to 80 rods in width and 20 feet in depth. At the north line of the town of Darien this channel swings westward away from the morainal front. Near the east line of Rock County it turned to the south and finally joined the flow from the Turtle Creek outlet at a point one-half mile east of Fairfield post-office. The valley at this point is now 60 feet in depth.

ORIGIN OF LAKE GENEVA AND LAKE COMO.

With the retreat of the glacier to the Elkhorn moraine is to be associated the origin of Lake Geneva, one of the most beautiful of Wisconsin's many lakes. This lake, situated in southern Walworth County, is nearly 8 miles in length; its width varies from one-half mile to 2 miles, and the bottom of the trough in which it lies is 200 to 400 feet below the crests of the Elkhorn moraine on the north, the Darien moraine on the south, and the ridge, supposed to be the extension of Marengo Ridge, on the west. At the east the trough is more open, yet, instead of deepening toward the outlet, the lake gradually shallows in this direction. The lake reaches its greatest depth, 142 feet, in the western part, between Camp Collie and Cooks Camp. At the foot of the lake there is but a few feet of water. It is very evident that the basin was not produced by post-Glacial erosion.

The mode of its formation appears to be this: The earlier glacier of the Wisconsin stage, which formed Marengo Ridge, moved westward down the pre-Glacial Geneva Valley to its junction with Troy Valley. During the advance the valley afforded a line of discharge for the glacial waters, which flowed southward through Troy Valley. When the advance ceased Marengo Ridge was formed as a terminal moraine. This drift dam blocked the outlet of the valley, but where it crossed the pre-Glacial depression there was a considerable sag in its crest. Through this sag much water from the final melting of this glacier escaped,

and this trenched the drift dam and kept the valley open. The tributary valley in which lies Lake Como discharged its waters into Geneva Valley by the way of Williams Bay. It is not improbable that these valleys afforded the principal outlet for the glacial waters of western Kenosha, southern Racine, and southeastern Walworth counties, until the ice front had retreated 25 to 35 miles to the eastward.

During the late Wisconsin invasion the ice of the Delavan lobe advanced southward across Geneva Valley and formed the Genoa and Darien moraines, the latter of which again blocked the outlet of Geneva Valley, at the same time leaving that part of the valley within the moraine unfilled with drift. There is a sag in the crest of the Darien moraine opposite the head of the lake, but its elevation, 1,000 feet above the sea, is so much greater than that of the Nippersink outlet at Genoa Junction that the westward discharge of the waters was not resumed on the withdrawal of the ice front to the Elkhorn moraine. The valley thus remains closed by a 280-foot dam of drift. When the Elkhorn moraine was formed the valley occupied by Lake Como was cut off by the morainal deposit between the heads of Lake Como and Williams Bay, and the last of the drift composing the bulky ridge to the east was deposited.

The south slope of the ridge north of Lake Geneva, on which the ice front rested for a time, shows considerably more erosion than does the north slope of the same ridge; this was not improbably due to the discharge of the glacial waters into the lake basin. Probably, also, more or less material was washed into Williams Bay at this time, and at the foot of the lake the gravel terrace on which the village of Geneva stands was formed. The remarkable thing, however, is that the basin did not receive more filling than it did. The ice must have continued longer in the basin than on the neighboring ridges, so that a filling of ice may have prevented any considerable filling with drift until the ice front abandoned the crest on the north. The disappearance of the ice from the White River and Como valleys left the lakes in their present conditions, excepting that the level of Lake Geneva is now maintained by an artificial dam.

ORIGIN OF DELAVAN LAKE.

It can not now be determined to what extent the pre-Glacial Troy Valley between Delavan Lake and the Sugar Creek Valley was filled by pre-Wisconsin drift. Farther to the northeast the trough was sufficiently open to bring about the development of the Delavan lobe, but in this part just north of the lake much of the great thickness of drift may be the remains of older sheets. The exposure of reddish till, like that of the older drift area, in the slopes north of the lake has raised a suspicion that the ridge there may be largely of older drift,

especially as the older and later drift come into closest proximity, with but little intervening outwash, immediately to the west and southwest of the lake basin. This can not, however, be regarded as very good evidence, since the origin of the reddish coloring matter of the drift in this region was apparently the red beds of the lower part of the Niagara formation, which are found just beneath the drift in the vicinity of Lyons and Burlington, directly to the east of Delavan Lake, and the contributions of red material were to both the older and the later drift.

The elevated tract between this lake basin and Lake Geneva is regarded as probably due to the burial of the northwestward extension of the Marengo Ridge. During the early Wisconsin glacial invasion, while the glacial front stood at the Marengo Ridge as a terminal moraine, the water from the melting ice would be discharged into the lower area to the northwest and west, and would flow off thence to the south through Troy Valley. If the valley north of the site of the lake was largely blocked with drift, the waters would be confined to a distinct channel bordering the moraine, where they would scour out rather than make any considerable deposits. Considerable water may also have come from the northeast, near the morainal front along the line of Jackson Creek Valley, the northeastward extension of the lake basin.

When the later invasion of the Wisconsin stage took place the Delavan glacial lobe advanced over this area, deposited the Darien moraine transversely across whatever filling of older drift there may have been in Troy Valley, across the supposed northward extension of the Marengo Ridge and the intervening trough, and was melted back to the Elkhorn moraine without entirely obliterating the earlier drift features. The damming of the valley by the deposition of the Darien moraine inclosed the basin.

As in the case of Lake Geneva, a long finger of ice probably continued in the basin after the ice had disappeared from the higher areas on either side. That this really is the case there is indication in the peculiar location of the little valley just south of the lake. The position of the little valley, which was probably developed by the glacial waters when the ice front stood at the Elkhorn moraine, looks as though a mass of ice lying in the basin had held a stream halfway up the gentle slope to the southeast and forced it to cut a channel there. As the ice melted, the waters in the basin overflowed at the lowest point and there developed the present outlet.

While these hypotheses of the origin of these three lakes are not without objections, they at least afford fairly satisfactory explanations of how the basins may have been formed under the conditions afforded by the several glacial advances and retreats.

A. BALD BLUFF, A PROMINENT SALIENT OF THE INNER OR WEST FACE OF THE KETTLE RANGE, 2½ MILES SOUTHWEST OF PALMYRA, WIS., AS SEEN FROM THE SOUTHWEST

B. KAMES NEAR BASS LAKE, 5 MILES SOUTHEAST OF WHITEWATER, WIS.

INTERLOBATE KETTLE MORAINE.

Character and mode of formation.—Reference has already been made (p. 10) to the comprehensive system of moraines grouped under the terms Kettle Range or Kettle moraine. Professor Chamberlin states that the first portion of the Kettle moraine to receive systematic investigation and a specific determination of the true nature and method of its formation was that part lying between and formed by the joint action of the Green Bay and Lake Michigan glaciers, and it was this part, locally known as the Kettle Range, which gave the name to the whole system. This portion, referred to in one place[a] as the "Kettle Range proper," Professor Chamberlin recognized as belonging to a distinct type of moraines, for which he proposed the name Intermediate or Interlobate moraines,[b] from which is taken the designation "interlobate Kettle moraine," used in this paper for that portion of the moraine lying between the two glaciers. Professor Chamberlin pointed out the fact that while such moraines, lying in such a singular way between two adjacent glacial lobes, have some likeness to medial moraines, they are not such in any proper sense.

"The true medial moraine consists of superficial matter borne passively on the surface of the glacier, having been formed by the junction of lateral moraines in the union and coalesence of two glaciers, which then move forward as one, the moraine lying longitudinally to the glacier and parallel to its motion. But, on the contrary, the intermediate portions of the Kettle moraine lie along the face of two approaching ice sheets, which may have met and antagonized each other to some extent, but did not coalesce; and, furthermore, they lie transverse to the glacial motion and are strictly marginal, and are, in real nature, terminal moraines, differing from other portions simply in being formed by two glaciers pushing from opposite directions."

Parts of the interlobate Kettle moraine have already been discussed. This moraine is, however, of so composite a character that it may be well, before proceeding further with the discussion of the deglaciation of the area, to consider as a whole that part of the moraine which lies within this area.

The effect of the longer continuance of the Green Bay Glacier at the interlobate Kettle moraine north of the vicinity of Bass Lake after the ice front on the east had withdrawn somewhat was to give to this moraine, to a large extent, the characteristics of an ordinary terminal moraine of the Green Bay Glacier, though the beginning of the deposition in all its parts was probably as a true interlobate moraine. From the vicinity of Richmond northeastward into Waukesha County the Kettle moraine is continuous, but its course is more or less zigzag, shifting from northeast to east in two places. These shifts are believed to be due to the relations of the two ice fronts during the successive

[a] Chamberlin, T. C., Preliminary paper on the terminal moraine of the second glacial epoch: Third Ann. Rept. U. S. Geol. Survey, 1882, p. 321.

[b] Geol. Wisconsin, vol. 1., p. 276.

stages of the retreat. This moraine, as it is seen to-day, was probably developed by stages from southwest to northeast. At the first stage the Darien and Johnstown moraines for a distance of 7 miles northeast of the village of Richmond were combined into a continuous interlobate deposit, whose constituent parts are, however, more or less readily discernible. This portion, which has already been discussed, is really the only portion within this area which was completed as an interlobate moraine. The two glaciers appear to have abandoned this portion of the moraine simultaneously.

During the second stage the next 3½ miles, between a point north of Bass Lake and Lagrange Center, was completed as a part of the Milton terminal moraine of the Green Bay Glacier. This part of the moraine has a more easterly trend and is bordered on the south by the outwash plain on which stands the village of Heart Prairie. The point of junction of the two ice fronts at this stage was near the village of Lagrange Center. From this angle the main crest of the moraine, which is on the Green Bay side of the deposit, runs north 2 miles to Bald Bluff, a prominent salient (Pl. VIII, A), and thence northeastward 3 miles to the vicinity of the village of Palmyra. On the east and southeast of the Green Bay crest the deposit spreads out in a broad belt with pitted topography, resulting from the combination of the Milton morainal deposits with those of the Elkhorn moraine and more or less outwash material into an interlobate deposit like that extending northeastward from the vicinity of Richmond.

Many large depressions occur in this interlobate area to the west and to the northwest of the village of Lagrange Center. Beginning about 1 mile northeast of this place and extending thence nearly 1½ miles northward is an irregular, elongated depression which in its deepest part is 80 feet in depth. This has no outlet, the gravel slopes are abrupt, and the bottom is broken by knobs, ridges, and kettle holes. At two places the east front of the Green Bay crest drops abruptly 80 to 90 feet to the bottoms of narrow depressions, from which abrupt slopes rise 60 to 90 feet to what appears to be an outwash plain beyond. Numerous depressions of less depth are similarly situated. Over several square miles the area is very much broken by depressions, though here and there occur bits of flat plain topography.

The moraine on the west side of this area is strongly developed, with a ridged crest rising 20 to 80 feet above the interlobate deposits, but on the east the morainal and outwash deposits are not readily distinguished. From these relations it appears that, as the frontal slope of the Delavan lobe was melted back, the vigorous outwash from the opposing glacier buried much of the marginal ice of the Delavan lobe, from which resulted the remarkably broken character of this interlobate deposit.

A. PARTIAL SECTION OF THE KETTLE RANGE AT THE ABANDONED RAILWAY CUT AT TREE BLUFF, 4 MILES SOUTHEAST OF WHITEWATER, WIS., SHOWING THE NARROW CREST AND THE COARSENESS AND LACK OF ASSORTMENT OF THE MATERIAL.

B. LAKE CLIFF AT RACINE, WIS.

In southern Jefferson County, near Palmyra, the moraine again swings toward the east, which course it maintains to the vicinity of the village of Eagle, in southwestern Waukesha County. Here the morainal crest is marked by a series of more or less parallel gravel ridges, which alternately coalesce and diverge, giving rise to a complex topography. The frequent depressions in the bordering outwash deposits indicate that much of the marginal ice of the Delavan lobe was buried by the outwash between the two ice fronts. From the village of Eagle to a point about 5 miles north, the moraine lies partly close to and partly upon the crest of the low Niagara escarpment. Here it has a breadth of one-half to 1 mile. On the west is a low marshy tract underlain by the Cincinnati shale. The combined relief of the escarpment and the moraine varies from 100 to 200 feet. Of this relief, about 100 feet is due to the morainal deposits. From the crest the east slope drops down to an outwash terrace 20 to 40 feet below. This terrace, which, for the most part, is nearly flat, varies in width from 80 rods to 1½ miles. It declines eastward to an abrupt slope, where the surface drops down 20 to 40 feet to a second terrace.

Farther north the Green Bay Glacier overrode the Niagara escarpment and pushed some distance down the gentle east slope. Here the west front of the moraine has a relief of 80 to 100 feet. The outwash plain becomes rougher and, with the narrow moraine, merges into a broad morainic tract over 3 miles in width. Four miles farther north the whole belt narrows again to a width of 1 mile.

From the relations in the vicinity of Eagle it appears probable that the Delavan and Green Bay ice fronts were still closely opposed as far south as the north end of the upper outwash terrace when the terrace was being formed. Farther south the glacial margins diverged slightly and the broad interlobate morainal belt divided into two narrower moraines, with a gravel terrace between them. At the succeeding stage the eastern moraine, which was probably weak, and much of the intervening gravel terrace were cut away by erosion.

Structure of the interlobate Kettle moraine.—The interlobate Kettle moraine is one of the unique features of this area. It is, as a whole, a bulky ridge, bordered on the east by the outwash deposits already described. The surface of this ridge is marked by a knob-and-kettle topography which varies greatly in detail from place to place. At one place there may be a series of gravel ridges not unlike railroad embankments, arranged nearly parallel to each other and to the trend of the moraine. Traced longitudinally for a short distance, these ridges become winding, inclosing deep irregular depressions, with side slopes often as steep as 30° to 35°, or they may break into more or less distinct conical knobs, irregularly distributed and interset with equally abrupt round or irregular depressions. Differences in elevation of 20 to 100 feet occur within the space of a few

rods. The close and irregular distribution of these features, and the variation in the heights of the knobs and ridges and in the depths of the hollows at many places, combine to form a perfect wilderness of humps and hollows.

On one side such an area may be flanked by a high, flat-topped, table-like ridge; on the other, the reliefs may become less and the surface soften to one of gentle sags and swells, or there may be small inclosed basins 20 to 300 acres in extent, where the surface is gently undulating or nearly flat, affording tillable fields. The reliefs in general decrease from west to east, and there is usually a gradual change from the topography of the moraine to that of the bordering outwash terrace.

The composition of this moraine, as shown by the numerous exposures and by the records of wells within the morainal belt, is very largely of coarse gravel. One of the best exposures is that afforded by the abandoned railroad cut 4 miles southeast of Whitewater. The northwest or inner face of the moraine at this place has a relief of 140 to 180 feet and an angle of slope of 30° to 35° at the exposure shown in Pl. IX, *A*, which shows the narrow crest of the abrupt morainal ridge and the upper half of the 60 to 70 foot section. There is little or no evidence of assortment and stratification. The material is mostly coarse gravel and bowlders, but with this is considerable buff clay. There is very much coarse material, many of the blocks containing 5 to 10 cubic feet of rock. The gravel is well waterworn, but much of the larger material shows comparatively little wear. The greater part both of the coarse gravels and of the larger blocks is from the Galena and Trenton limestones. A few rods northwest of the point where this view was taken an exposure in the northwest slope shows similar coarse material, below which is coarse sand showing undisturbed strata dipping toward the southeast.

A 50-foot section is afforded by the road cut through the morainal crest 1 mile southeast of Palmyra. Here the gravels, which range in size from a fraction of an inch to 8 inches in diameter, are generally well rounded. In the upper part of the section the gravels are stratified; lower down the structure was obscured when seen. The stratified gravels run laterally into very stony till.

A third partial section of the moraine is that afforded by the gravel pit of the Chicago, Milwaukee and St. Paul Railway 1 mile west of the village of Eagle. This section when visited was 20 to 30 feet in height and about 40 rods long. The material ranges from clean waterworn gravel an inch in diameter to bowlders 2 feet in diameter. The longest diameters of the majority of the stones are between 2 and 8 inches. There is so little of clay or of cementation that the gravels slide down readily through the full height of the section when excavated, so that whatever stratification is present is obscured in the exposure.

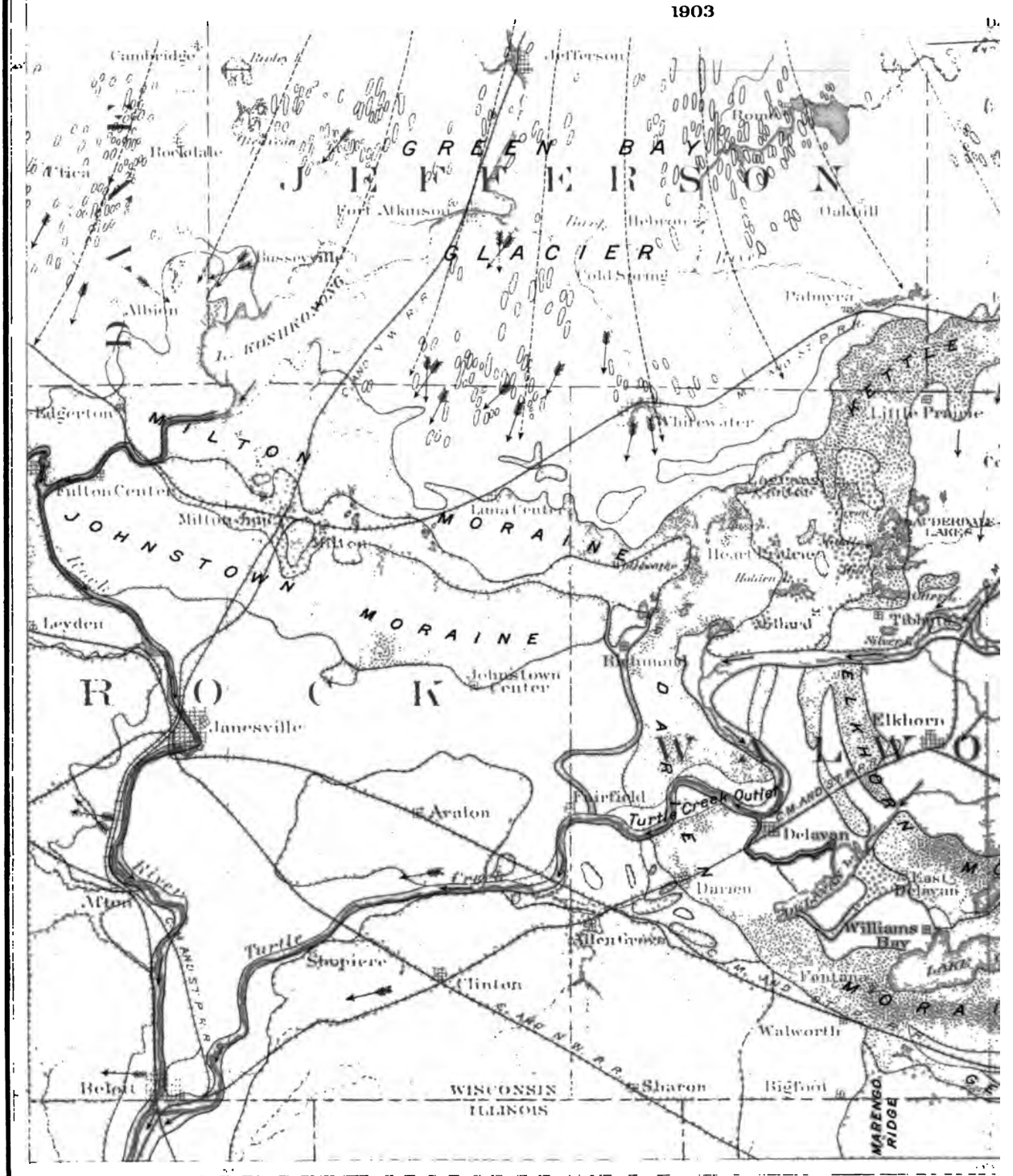
MAP OF A PORTION OF SOUTHEASTERN WIS

AT THE TIME OF THE FORMATION OF THE FIRST GRAVEL
SHOWING THE RELATIONS OF THE LAKE MICHIGAN GLACIER, INCLUDING
TO THE GREEN BAY GLACIER AND OF THE MORAINES AND ATTEN
DEPOSITS TO THE EARLIER DRIFT DEPOSITS

BY WILLIAM C. ALDEN

Scale
0 1 2 4 6 8 10 miles

1903



N
E,
LAVAN LOBE,
TWASH
North Milwaukee
Wauwatosa
Elm Grove
C. M. AND ST. P. R. R.
Wales
Waukesha
North Greenfield
AND N. W. R. R.
MILWAUKEE AND MADISON LAKE
New Berlin
Genesee Depot
Saylesville
Prospect
Dales Corners
North Prairie
Toss Corners
Little Muskego L.
Muskego
St. Martin
Jericho Corners
Big Bend
Eagleville
Mukwonago
Durham
DELAVAN
Caldwell
Tishigan L.
Lake Beulah
Potter L.
East Troy L.
GLACIAL
East Troy
North Cape
Waterford
LOBE
Honey Creek
Rochester
Yorkville
Vienna
Eagle L.
Dover
C. M. AND ST. P. R. R.
Rochester
Union Grove
Burlington
Lyons
VALPARAISO
Shades Corners
Bristol
Silver Lake
Salem
Montgomery L.
Camp L.
George L.
Trevor
Wilmot
Antioch

FORMATION OF THE FIRST GRAVEL TERRACE, ON WHICH STAND THE VILLAGES OF EAGLE AND LITTLE PRAIRIE.

The stages of the glacial retreat after the withdrawal of the ice fronts from the Elkhorn and Milton moraines were marked by a complicated series of phenomena not lending themselves readily to positive correlation. The correlation here presented, however, affords a fairly satisfactory explanation of the different features.

Northeastward from southeastern Jefferson County (Pl. X) the front of the Green Bay Glacier was still crowded against the west face of the interlobate Kettle moraine, though farther south it may have begun to withdraw from the Milton moraine. Some slight morainal deposits lying just north and west of the inner margin of the Milton moraine in northwestern Walworth County and northeastern Rock County probably mark the beginning of the withdrawal from this moraine, though the exact time of their formation is not evident from the relations.

On the east the Delavan ice front continued to retreat, so that a widening interlobate angle formed in the vicinity of the village of Little Prairie and extended northeastward into Waukesha County, to a point 5 miles north from the village of Eagle. Beyond this point the two ice margins were still closely opposed, while the upper terrace which borders the interlobate Kettle moraine in the vicinity of Eagle was being formed by the outwash.

In northern Walworth County, where the front of the Delavan lobe lay across Troy Valley, the morainal deposits are so largely buried in outwash material that no continuous moraine can be traced. About 2 miles northwest of the village of East Troy (Pl. X) there is an undulating area, about 1 square mile in extent, whose bowlder-strewn surface rises 80 feet above the general level of the surrounding plain. It is possible that this and some similar smaller elevations may belong to this moraine. Over the elevated tract south of Troy Valley there are occasional groups of gravel knolls, but there is no well-defined moraine. The retreat of the ice front across this area was evidently so continuous that no moraine was formed. The junction of the Delavan ice front with that of the main Lake Michigan Glacier at this stage was somewhere between Rochester and Burlington, probably not far north of the latter place.

From Lauderdale Lake to the village of Mukwonago the surface of the drift is pitted by a remarkable series of depressions, the result of the burial of the marginal parts of the disintegrating Delavan glacial lobe by morainal and outwash deposits while the Elkhorn moraine and the first terrace at Eagle were being formed and during the immediately following stages of the retreat. The character of the

topography thus produced is shown on Pl. XI, which is reproduced from the Eagle and Whitewater sheets of the Topographic Atlas of the United States.

The largest and most notable of these depressions is the very irregular branching valley, 10 miles in length, in which lie Lake Beulah, East Troy, Phantom, Eagle, and Lulu lakes, and an extensive marsh. That these larger depressions are essentially connected series of kettle holes and can not be due to fluvial erosion is shown by the exceedingly abrupt and irregular marginal slopes and by the inequalities in depth where not now occupied by marsh deposits (Pl. XII). The lakelets, ponds, and marshes occupying these depressions in many cases lie 50 to 80 feet below the surrounding plain. The marginal gravel slopes are very abrupt and are often made exceedingly irregular by kettle holes, knobs, and hogback ridges. Some of these ridges extend one-half mile or more out into the marshes, above which they rise 50 to 70 feet, and some of the crests are so narrow that two teams could not pass upon them, while the slopes drop down at angles of 30° to 35°.

The character of the deposits is shown by the following wells on this first terrace:

Log of W. S. Watson's well in the village of Little Prairie.

	Feet.
Gravel	40
Hardpan	40
Sand	40
Hardpan	2
Gravel	4
Depth	126

Log of Robert Cross's well, 2 or 3 miles south of the village of Little Prairie.

	Feet.
Stony clay	16
Gravel and sand	125
Stony clay	?
Gravel	?
Depth	254

Log of McKee Brothers' well, 5 miles west of the village of East Troy.[a]

	Feet.
Blue clay	66
Sand	160
Hardpan	4
Layers of hardpan each 3 or 4 feet thick alternating with layers of sand	171
Rock	3½
Depth	404½

[a] Information furnished by W. L. Thorne, a well driller of Whitewater, Wis.

There is nothing to show how much of the drift penetrated by these wells is to be referred to the advance and how much to the retreat of the Delavan Glacier, nor what part may have been deposited during earlier stages of glaciation.

The disposition of the glacial waters at this stage was of considerable importance. The drainage from that part of the Green Bay Glacier lying southwest of the village of Palmyra probably escaped to Rock River by way of the low tracts bordering the inner margin of the Milton moraine (Pl. X); that from the Green Bay front east and northeast of Palmyra, from the interlobate angle near Eagle; and that from the front of the Delavan lobe as far south as the divide south of Sugar Creek Valley, through the Turtle Creek outlet near Delavan and thence to Rock River at Beloit. A part of this water reached the Turtle Creek outlet near Delavan by the way of Jackson Creek Valley through the Elkhorn moraine, south of the city of Elkhorn. South of Sugar Creek Valley the glacial waters continued to flow to the Nippersink outlet at Genoa Junction. The gravel deposits on which stand the villages of Springfield and Lyons were probably formed as deltas at the débouchures of the valleys by the water coming from the elevated area to the north. Probably also about this time the gravels underlying Gardners Prairie, northwest of Burlington, were deposited as an outwash deposit.

Two miles west of the village of Vienna a small valley heads in a sag in the south slope of Sugar Creek Valley, and leads thence southward to the White River bottom northeast of the village of Lyons. This valley is eroded to a depth of 40 to 100 feet, yet there is now scarcely any area tributary to it except its own immediate slopes, so that it contains no stream and shows very little evidence of recent erosion, such as marks the valley one-half mile west. This little valley was evidently not due to post-Glacial erosion. It was probably developed by the glacial waters at this time.

ORIGIN OF SUGAR CREEK VALLEY.

The peculiar relationships of Sugar Creek Valley, which cuts through the elevated ground-moraine area northeast of Elkhorn (Pl. X), probably can be explained by the drainage conditions of this stage. The relationships are these: In the first place, the amount of erosion required for its excavation is not equaled, in the area of the later drift examined by the writer, in any valley having so limited an area of tributary drainage. Its flat, marshy bottom varies in width from 40 rods to nearly one-third of a mile, and through this bottom meanders a rivulet so small as to be out of all proportion to the capacious valley. Sugar Creek heads in a narrow, marshy tract north of Elkhorn, which is also drained by the head of Turtle Creek on the west and by the head of Honey Creek on the north. The valley leads from the low marshy area, 900 to 920 feet above the sea, to a low area northwest of Burlington having an elevation

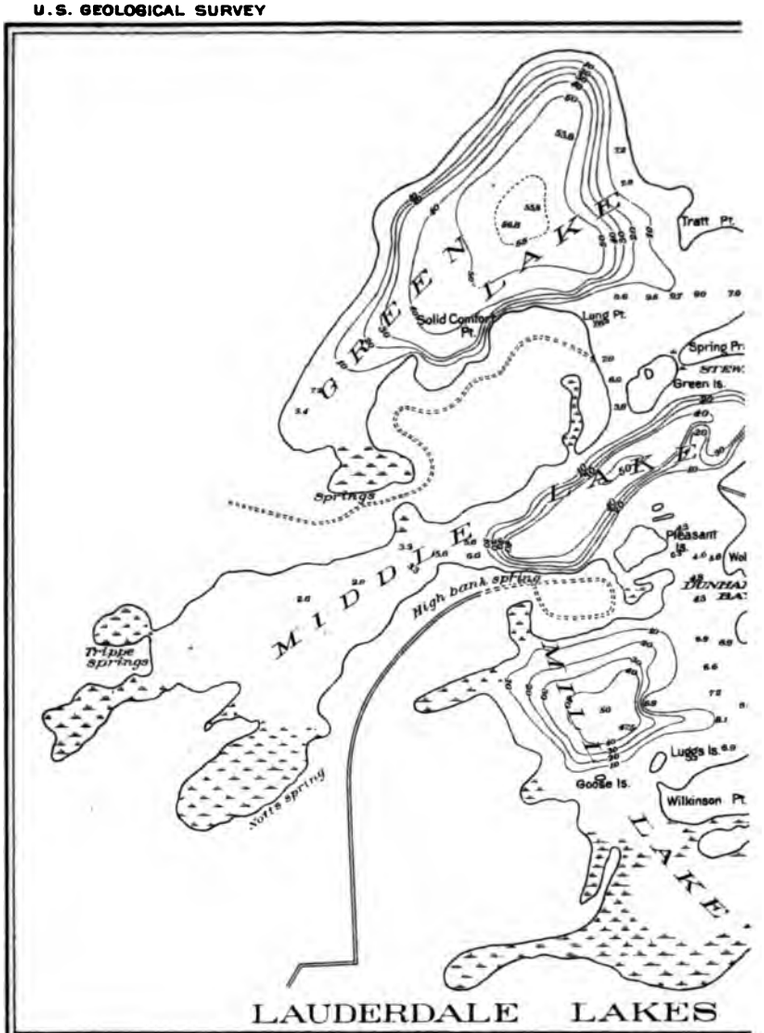
of 760 to 800 feet. In doing so it cut through an elevated track, which, in its highest part on the immediate crests of the valley slopes, reaches an elevation of 1,040 to 1,060 feet above the sea. Moreover, but very little of this elevated area is tributary to this valley. Thus it is evident that the valley of Sugar Creek could not have been developed under the ordinary conditions of erosion.

There is no evidence of an underlying pre-Glacial valley which might have caused a sag in the drift surface of such depth as to cause the drainage from the west to follow this line in preference to Turtle Creek on the west or Honey Creek on the north. In fact, the rock is exposed at one point in the valley bottom, and wells to the north and the south indicate that the elevation of the rock there is about the same as in the valley exposure. We must therefore look for special conditions for the explanation of this valley.

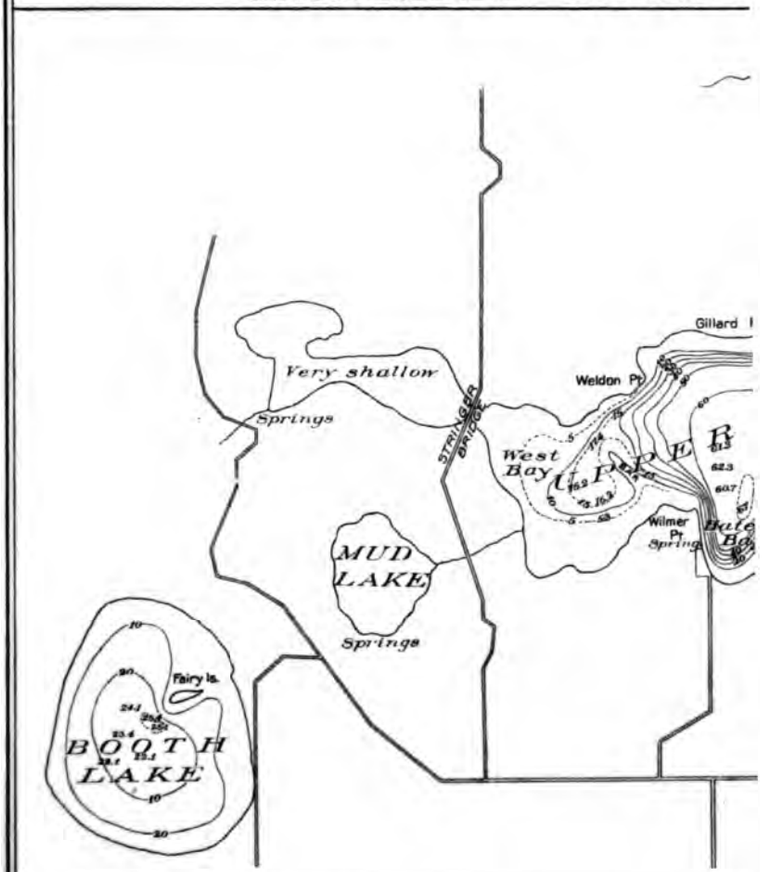
These conditions were probably furnished by the ice front retreating toward the northeast from the Elkhorn moraine. It is not improbable that there was an initial sag in the drift surface. This sag would be deepened by water flowing westward to Turtle Creek from the retreating ice front, so long as the glacier lay across the line of the valley. The valley thus extended eastward and trenched the highest part of the area nearly to the level of Turtle Creek Valley, northwest of Elkhorn. When the ice front had withdrawn entirely from the line of the valley the drainage began to flow to the lower area to the east, and the valley was further deepened by cutting back in the opposite direction. In this manner it is probable that the divide was cut down until it was lower than the valley leading to Turtle Creek outlet near Delavan. As soon as this was accomplished the whole of the glacial drainage from the ice fronts north of this newly opened valley was diverted eastward to the valley leading to the Nippersink outlet at Genoa Junction. This diversion accomplished, the abundant flow further deepened Sugar Creek Valley, and the Turtle outlet was abandoned.

FORMATION OF A SECOND GRAVEL TERRACE, IN SOUTHWESTERN WAUKESHA COUNTY AND NORTHEASTERN WALWORTH COUNTY.

The diversion of the glacial drainage from the Turtle outlet through the Sugar Creek Valley to the Nippersink outlet marks the next stage in the deglaciation of the area (Pl. XIII). The continued melting of the Delavan glacial lobe carried the margin back to the moraine lying in southwestern Waukesha County, just west of the villages of Genesee and Genesee Depot. The ice lay across the elevated ground moraine tracts between the village of North Prairie and the village of Mukwonago, and continued in Troy Valley, while the south margin of the lobe was being melted back to the line of gravel hills lying 2 miles east of the village of East Troy.



LAUDERDALE LAKES



noted, there is no evidence that outwash from the Green Bay Glacier crossed this upper terrace and marginal slope to the lower terrace, whence it is inferred that the outwash from the west had ceased and that the Green Bay Glacier had abandoned the moraine.

FORMATION OF A THIRD GRAVEL TERRACE, IN SOUTHWESTERN WAUKESHA COUNTY AND NORTHEASTERN WALWORTH COUNTY.

By the time the second terrace had been completed and the ice front had been melted back to its next line of morainal deposits the lobation of the west margin of the Lake Michigan Glacier had become very slight. This was all that remained of the Delavan lobe (Pl. XIV). The ice front still stood at the moraine in the vicinity of the villages of Genesee and Genesee Depot, but farther south it had retreated to the vicinity of Mukwonago, leaving great masses of ice buried in the gravels in Troy Valley. The great depressions resulting from the subsequent melting of these ice masses have already been described (Pl. XI). In the vicinity of Mukwonago the ice front lay to the north and east of the village, along the morainal deposits which block the converging tributaries of the pre-Glacial Troy Valley. South of this the morainal deposits of this stage are found between the villages of Lake Beulah and Caldwell Prairie. Northwest of the village of Waterford they connect with the Valparaiso moraine of the Lake Michigan Glacier. For 2 miles below the village of Rochester the ice may have continued at the moraine west of the river, but farther south Fox River Valley must certainly have been clear by this time.

This stage was thus marked by the opening of the lowest outlet for the glacial drainage yet available, that by way of Honey Creek to Burlington and thence by Fox River to Illinois River. When fully cut down, the elevation of this channel at the west line of Racine County, about 3 miles north of the village of Honey Creek, was about 800 feet above the sea, while that of the head of Sugar Creek Valley north of Elkhorn is at an elevation of 860 to 870 feet. At the State line the channel of Fox River is about 740 feet above the sea, while the Nippersink outlet at Genoa Junction is about 830 feet. The greater fall by way of Honey Creek and Fox River thus gave it a great advantage over the outlet by way of Sugar Creek Valley and the Nippersink outlet, so that this latter outlet in its turn was abandoned. This opening of a lower outlet for the glacial drainage resulted in a further acceleration of the flow, and, as a consequence, the second terrace east of the village of Eagle was itself in part eroded and a third and still lower terrace was formed.

The distinction between the second and third terraces is most plainly marked in the area southwest of the village of Jericho Corners, in southwestern Waukesha

MAP OF A PORTION OF SOUTHEASTERN WIS

AT THE TIME OF THE FORMATION OF THE SECOND GRAVEL
SHOWING THE RELATIONS OF THE LAKE MICHIGAN GLACIER, INCLUDING
TO THE GREEN BAY GLACIER AND OF THE MORAINES AND ATTEN
DEPOSITS TO THE EARLIER DRIFT DEPOSITS

BY WILLIAM C. ALDEN

Scale
0 1 2 4 6 8 10 miles

1903

AVAN LOBE,
WASH
North Milwaukee
Wauwatosa
Elm Grove
C. M. AND ST. P. R. R.
Wales
Waukesha
Northgreenfield
AND N. W. R. R. MILWAUKEE AND MADISON LINE
New Berlin
Genesee Depot
Saylesville
Dousman
Eagles Corners
Toss Corners
Little Muskego L.
Muskego
St. Martin
DELAVAN GLACIAL LOBE
Big Bend
Mukwonago
Durham
Caldwell
Lake Beulah
Tichigan L.
Wind L.
North Cape
Thompson
Waterford
Rochester
Yorkville
Creek Valley
Eagle L.
Dover
C. M. AND ST. P. R. R.
Kansasville
Union Grove
Burlington
Lyons
Prairie
Bristol
Hooker L.
Salem
Montgomery L.
Camp Lake
George L.
Trevor
Wilmot
Antioch
BOUNDARY LINE
Richmond
Fox River
Illinois
Wisconsin

County, where, for nearly 2 miles, a short, abrupt slope of 15 to 20 feet separates the plain of the second terrace from a like lower plain. At Jericho Corners and at several points between this and the village of North Prairie the gravels were so far removed as to expose the underlying rock. A remnant of the second terrace is seen in the flat-topped ridge extending northward from a point three-fourths of a mile north of Jericho Corners.

The morainal and outwash deposits in the vicinity of Mukwonago completely closed the branches of Troy Valley to further southwestward drainage, and gravel and sand were deposited around and over the ice masses remaining in the Troy basin, thus completing their burial. In general, the elevation of these outwash deposits decreases toward the head of Honey Creek outlet at the west line of Racine County. In the western part of Racine County sand and gravel were washed out through the sags leading between the ridges of the ground-moraine till to the valley of Honey Creek. Sand and gravel deposits also border Fox River more or less continuously from Burlington to the State line.

HEBRON MORAINE.

The stages of retreat of the front of the Green Bay Glacier can no longer be surely correlated with those of the Lake Michigan Glacier within the area under discussion. It is not improbable, however, that about the time of the formation of the third terrace east of the village of Eagle the front of the Green Bay Glacier stood at a weak morainal belt in southern Jefferson County, which may be traced, with some discontinuity, from a point 3 miles northeast of the village of Rome, where it enters this area from the northeast, in a broad curve southwestward, then westward, then northwestward past the village of Hebron and Fort Atkinson to the vicinity of Ripley Lake in western Jefferson County, and thence northwestward beyond the area under discussion (Pl. XIV). This morainal belt may be conveniently referred to as the Hebron moraine from its relation to the village mentioned.

In some parts this moraine is rather strongly developed and is bordered by terraces of sand and gravel. At other points the morainal deposits scarcely obscure the drumloidal topography which they overlie. The relations of the morainal belt extending northward near the Jefferson-Dane county line from the west end of Lake Koshkonong have not yet been fully determined. The further retreat of the Green Bay ice front carried it beyond the limits of the area under discussion.[a]

[a] Further examination of the area has resulted in tracing a very weak but distinct moraine from the vicinity of Rome westward through the Jefferson County farm, southwest of Jefferson, and thence northwestward beyond the limits of the area under discussion. This moraine marks the position of a halt of the retreating ice front about 2 miles north of the Hebron moraine.

Just how rapidly the morainal and rock barriers below Lake Koshkonong were cut down is not known, but it is probable that for some time the glacial waters were ponded between the Milton moraine and the retreating ice front of the Green Bay Glacier, forming an extensive lake which covered the lower areas of southern Jefferson County, northeastern Rock County, and northwestern Walworth County. Lake Koshkonong and the extensive marsh areas of the region are the remnants of this glacial lake. In trenching the drift and rock barriers near Fulton Center the stream had to cut through about 35 feet of drift and 50 feet of limestone and sandstone. Farther south, where the rock was not encountered, the amount of drift eroded was much greater. In time, if the artificial dams in Rock River are not maintained, Lake Koshkonong and the marshes will disappear as the river further deepens its channel. Laminated clays which were deposited in the glacial lake are exposed in the clay pits at the brick yards at Fort Atkinson and Jefferson.

VALPARAISO TERMINAL MORAINIC SYSTEM.

The next stage in the deglaciation of the area was marked by the entire disappearance of the Delavan lobe and by the opening of the valley of Fox River between Waukesha and Burlington. So gradual was the withdrawal of the main west front of the Lake Michigan Glacier that it was yet occupying the morainal belt bordering Fox River when the ice of the Delavan lobe had so far disappeared that its margin occupied the northward continuation of the same moraine (Pl. XIV).

The Valparaiso morainic system, where it enters Kenosha County, Wis., from Lake County, Ill., has a breadth of nearly 10 miles. The western part of the belt along Fox River is marked by discontinuous groups of kames forming bulky ridges, whose surfaces are pitted with kettle holes. These alternate with low, marshy tracts, and with nearly flat areas underlain by sand and gravel deposits. Farther east the topography is marked by broader undulations and depressions with abrupt ice-contact slopes, which are occupied by lakelets and marshes.

In the northern part of Kenosha County the morainal belt narrows and a distinct ground-moraine topography appears to the east. As far north as the vicinity of the village of Waterford, in western Racine County, there is a continuous bulky moraine, such as would be expected from so long occupancy by the front of the Lake Michigan Glacier. From this place northward to the vicinity of Waukesha, where the occupancy by the ice front was very much shorter, the morainal deposits, though spread over an area of considerable width, are very much scattered and are insufficient in amount to obscure the drumloidal ground-

moraine topography developed during the advance of the glacier.[a] Evidences of a morainal stage in this part are found in patchy areas with pitted topography, sags and swells, occasional gravel knolls, and the very great abundance of surficial bowlders.

Perhaps the most notable deposit of this stage of the retreat is the great abundance of bowlders scattered over the high region between Waukesha and the Muskego lakes. These bowlders have been very largely collected from the fields and piled in walls along the fences. In some parts of this tract there are many fields inclosed by walls of bowlders 3 feet or more in height. In a certain pasture lot about 1 mile west of Little Muskego Lake, where the bowlders appeared to be about as originally deposited, neither having been collected nor having received additions from adjacent fields, the writer counted 4,200 bowlders in less than 2 acres. It was possible to have crossed this lot by stepping from one stone to another. Of these bowlders less than 1 per cent were of other than foreign crystalline rock.

Besides the gravels bordering Fox River in Racine and Kenosha counties, there is a gravel terrace nearly 2 square miles in extent on which stand the villages of Big Bend and Chamberlain, in southeastern Waukesha County. Other like terraces occur farther north, the city of Waukesha standing on one of these.

As is shown by the previous discussion, if the writer's correlations are correct, the Valparaiso morainic system, as developed in Illinois and in southern Kenosha County, Wis., is the equivalent of all the morainal belts of the Delavan glacial lobe. That the Delavan lobe and the Green Bay Glacier were contemporaneous in the occupancy of their outer terminal moraines there can be no doubt. Whence it appears that the front of the Lake Michigan Glacier occupied the Valparaiso moraine at the same time that the Johnstown moraine was being formed by the Green Bay Glacier, and that it continued at this morainal belt in northeastern Illinois and southeastern Wisconsin even after the Green Bay Glacier had begun its retreat. The Valparaiso moraine in Illinois, as described by Mr. Leverett,[b] the Genoa and Darien moraines, as described in this paper, and that part of the Kettle moraine which in this paper is designated the Johnstown moraine of the Green Bay Glacier, thus mark the limit of the last glacial advance of the late Wisconsin stage of glaciation in southern Wisconsin and northeastern Illinois. The deposits of the early Wisconsin glaciers in southern Wisconsin were almost entirely overridden by the shifted ice lobes of the later invasion.

[a] Further examination of the area has resulted in grouping these scattered morainal deposits into two or three fairly distinct belts crossing the towns of Waukesha and Vernon from southeast to northwest. These are branches of the Valparaiso moraine, and their disposition indicates more of a lobation of the west margin of the glacier at this stage than would appear from the above description and from Pl. XIV.

[b] The Illinois glacial lobe: Mon. U. S. Geol. Survey, vol. 38, 1899, p. 399 et seq.

LAKE-BORDER MORAINIC SYSTEM.

As already noted, the Valparaiso morainic system is bordered on the east by a distinctively ground-moraine tract. East of this, in Milwaukee County, eastern Waukesha County, and the eastern halves of Racine and Kenosha counties, there is a series of broad, gentle ridges of drift which nearly parallel the shore of Lake Michigan. Mr. Leverett in his studies[a] found these same ridges continuing southward into Cook County, Ill., between the Valparaiso moraine and the lake shore. Similarly located ridges of drift were found in northwestern Indiana and southern Michigan, which were thought to belong to the same series. This system of ridges, which appears to mark further stages in the retreat of the Lake Michigan Glacier, has been designated by Mr. Leverett the lake-border morainic system. The distribution of these ridges in the area under discussion is shown on Pl. XIV. While in a large part of this extent the ridges are clearly marked and distinctly separated, so as to give the peculiar north-south trend to the drainage lines, they are cut through at intervals by the streams, and in some places contiguous ridges are coalescent, so that there may be some difference of opinion as to their exact correlation. This is, however, of little moment so long as the distinctive features of the topography are recognized.

It has been stated that when the front of the Delavan lobe reached the Valparaiso moraine in its retreat the lobe had almost disappeared. During these subsequent stages, however, there was enough lobation of the margin to give a marked westward shift to these lake-border ridges in Milwaukee County. This westward shift amounts to 6 or 7 miles, so that new ridges appear to the east, in northern Milwaukee and in Ozaukee counties, which have no correlatives at the south (Pl. III), or their southward continuations are to be found beneath the waters of Lake Michigan.

In general the topography of this lake-border belt differs but little from an ordinary ground-moraine area. Here and there groups of kettle holes pit the surface, and in some places considerable deposits of gravel occur, but for the most part the surface is marked by broad, gentle undulation. The notable feature of the tract is the disposition of the drift in broad ridges parallel to the lake shore, so that, though the general elevation decreases toward the east, the drainage reaches the lake only where the streams have cut transversely across the trend of the ridges, as in the case of Root and Pike rivers. One of the streams, Desplaines River, in fact does not enter the lake, but flows southward to Illinois River. Milwaukee River flows more than 30 miles between ridges of this lake-border system before it enters the lake at Milwaukee, though through most

[a] The Pleistocene features of the Chicago area: Bull. Chicago Acad. Sci., No. 2, 1897, pp. 42–47. The Illinois glacial lobe: Mon. U. S. Geol. Survey, vol. 38, 1899, pp. 380–412.

of this distance its course is within 3 miles of the lake, and at some points the shore is less than 1 mile distant. These ridges vary in width from 1 to 4 miles, and generally have longer east slopes and shorter west slopes, so that the elevations of the crests are successively lower on passing eastward to the lake. The crest of the west ridge stands 220 to 360 feet above Lake Michigan. The middle belt is marked by two more or less distinct crests, one of which is again subdivided.

The most sharply defined of these ridges south of Milwaukee is that lying nearest the lake shore. This ridge is continuous 25 or more miles southward, to Winnetka, Ill., where it is intersected by the lake shore. The crest of this ridge is 120 to 140 feet above the lake. It is thus 50 to 60 feet lower than the higher crest of the middle belt, and about 120 feet lower than that of the west ridge. The reliefs on the west sides of these ridges range from 20 to 60 feet, and on the east from 60 to 180 feet. The thicknesses of the drift penetrated by wells range from a few feet, where some buried rock ridges occur, to 300 or more feet where there are pre-Glacial valleys beneath. The bulk of the drift appears to be till, but extensive stratified beds are exposed in the lake-bluff section of the east ridge.

While the front of the Lake Michigan Glacier stood at the west ridge of the lake-border morainic system in Waukesha and Racine counties, the water from the melting ice was ponded over the low areas to the west or flowed directly to Fox River. The outflow evidently was not vigorous, as no outwash deposits have been found. Muskego and Wind lakes and the surrounding marshes are evidently the remnants of an extensive shallow lake formed at this time.

On the withdrawal of the Lake Michigan Glacier from the Valparaiso moraine in Illinois, Indiana, and Michigan a marginal lake was formed by the waters accumulating between the inner slope of the moraine and the retreating ice front. From Kenosha County southward the water discharged from the ice front, as it stood at the west ridge of the lake-border morainic system, flowed southward to this lake.

When the ice margin withdrew to the middle belt the flow of the glacial waters to Fox River ceased entirely. Thenceforward all the water from the melting glacier in the area under discussion went southward to this glacial lake by the valleys between these ridges. The final withdrawal of the ice front from the east ridge of this series allowed the expanding lake to reach southeastern Wisconsin, substituting lacustrine for glacial conditions in the eastern part of this area.

LAKE CHICAGO.

GENERAL RELATIONS.

As has already been indicated, as soon as the front of the Lake Michigan Glacier of the Wisconsin stage of glaciation had retired from the crest of the Valparaiso moraine in southwestern Michigan, northwestern Indiana, and northeastern Illinois the direct discharge of the glacial drainage into watercourses leading away from the ice front was obstructed, and the waters accumulated between the ice front and the crest of the moraine as a marginal lake. This glacial lake was initiated at the south and expanded northward with the melting of the ice. As the west margin of the glacier withdrew to the successive ridges of the lake-border morainic system, the intervening valleys became occupied by broad streams discharging southward into the glacial lake. It is even possible that the water overtopped the middle and east ridges. In the lake-border area of southeastern Wisconsin glacial and aqueous depositions were closely associated.

During these initial stages of the lake no distinct shore phenomena were developed, possibly because of the constant shifting of the water level as the barrier at the outlet was cut down, and because of the large amount of floating ice which obstructed wave action. The accumulating waters found an outlet near the south end of the basin, along the line of the present Desplaines River Valley, across the Valparaiso moraine southwest of Chicago, Ill. (Pl. III). Through this valley, known as the Chicago outlet, the waters found their way to Illinois and Mississippi rivers. The various phases of this glacial lake, to which Mr. Leverett has given the name "Lake Chicago," have been discussed in several publications.[a]

GLENWOOD STAGE.

The highest level at which a distinct shore line is now recognizable about the southern part of the basin is 640 to 650 feet above the sea, or 60 to 65 feet above the level of Lake Michigan. The shore line at this level has been designated the Glenwood shore line, from its strong development near the village of Glenwood, Ill., south of Chicago. Between Winnetka and Waukegan, Ill., the encroachment of the lake upon the land during the later stages has destroyed the ancient shore line, but from Waukegan northward to a point 5 miles north

[a] Andrews, Edmund, The North American lakes considered as chronometers of post-Glacial time: Trans. Chicago Acad. Sci., Chicago, 1870, pp. 1–24.

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Alden, W. C., Description of the Chicago district: Geologic Atlas U. S., folio 81, U. S. Geol. Survey, 1902.

of Racine, Wis., an old shore line is recognizable at a level corresponding to that of the Glenwood beach south of Winnetka, Ill. Through Racine and Kenosha counties this shore line lies between 1 and 2 miles west of the present lake shore. It is marked in places by a low cliff of till and a wave-cut terrace, but for the most part there is a well-developed ridge of beach sand and gravel lying on the gently rising surface of the till. These deposits occur mostly at levels between 50 and 60 feet above the present lake, though at some places limited deposits occur 70 to 80 feet higher than the present lake. East of this shore line there is a flat plain underlain by extensive deposits of lacustrine sands and clays.

Nowhere in Milwaukee or Ozaukee counties is this shore line now to be seen. For at least 11 miles northward from the point of intersection of the Glenwood shore line by the present lake bluff, in northeastern Racine County, the ancient beach has been destroyed by the encroachment of the lake upon the land during the subsequent stages. Farther north the relations are complicated by a deposit of red clay overlying stratified beach deposits.[a] It appears probable that these buried beach deposits are to be referred to the Glenwood stage, though this has not yet been fully demonstrated.

For the detailed discussion of the relations of the red clay deposit which borders the lake shore from Milwaukee northward and the underlying lacustrine deposits, reference should be made to the Milwaukee folio of the Geologic Atlas of the United States.[b] The correlation there presented is, in brief, as follows: It is suggested that the interstratified gravel, sand, and clay immediately overlying the till in the lower part of the lake-bluff section northward from a point about 5 miles southeast of Milwaukee harbor was deposited near the shore at the Glenwood stage of Lake Chicago, the front of the glacier having withdrawn an unknown distance to the north and east. From some unknown source there was introduced into the drift being deposited in the lake along the oscillating front of this glacier a tenacious red clay. Besides deposition directly from the melting ice front, the distribution of this clay may have been accomplished in part by floating ice. A part of it came within the zone of deposition near the shore, so as to be deposited as laminated clays interbedded with more or less material derived from the drift along the beach. It is further suggested that a readvance of the glacier occurred, crowding upon the land as far south as Milwaukee, overriding the stratified beds and leaving on them and on the till beyond their western limits the deposit of stony red clay now found bordering the lake from the vicinity of Milwaukee northward.

It has not yet been satisfactorily determined, however, whether this readvance

[a] Geol. Wisconsin, vol. 1, 1883, pp. 291–295, and vol. 2, 1877, pp. 219–230.

[b] Alden, W. C., Description of the Milwaukee district: Geologic Atlas U. S., folio — (in preparation), U. S. Geol. Survey.

of the glacier is to be correlated with the latter part of the Glenwood stage or whether the retreat of the ice front continued during this stage, reaching such a position as to allow the drawing down of the lake waters by some low outlet, to be followed by a readvance of the ice, blocking the outlet and reflooding the basin at the Calumet stage.

LOW-WATER STAGE.

The occurrence of a bed of peat beneath the deposits of the Calumet stage in the vicinity of Evanston, Ill., has led to the belief that, following the Glenwood stage, there was a time during which the waters were drawn down to a level even lower than that of the present lake, so that a part of the previously submerged area emerged.

Mr. Leverett[a] cites the deep channels in the lower courses of the streams tributary to the lake along the east shore in Michigan as also giving evidence of this emergence. He states that the soundings shown by the United States Lake Survey charts, from Pere Marquette Lake southward to Kalamazoo River, demand an emergence of at least 50 feet above the shore, even if the bottoms of the channels are but slightly filled. It is regarded as not improbable that the amount of filling is such as to necessitate the assumption of an even greater emergence in that region. The same writer's observations in the vicinity of Holland, Mich., led to the view that the channeling occurred subsequent to the formation of a strong beach which reaches 60 to 65 feet above Lake Michigan and prior to the formation of a beach which stands 25 feet above the lake. It was not, however, satisfactorily determined whether this emergence occurred between the Glenwood and Calumet stages or between the Calumet and Toleston stages.

Certain evidence of an interval of emergence was noted by the writer in the vicinity of Milwaukee harbor. It is possible, however, that the phenomena there observed were developed after, rather than before, the Calumet stage. They are discussed in a subsequent connection. It is probable that the cause of the low-water stage was the wasting of the Lake Michigan Glacier to such an extent that an outlet was opened to the northeastward which was lower than the Chicago outlet.

CALUMET STAGE.

Following the low-water stage the lake basin was again flooded and the southwestward discharge through the Chicago outlet was resumed. This second high-water stage was probably due to the closing of the northeasterly outlet. If the deposition of the red clay north of Milwaukee occurred at this stage the closing of this outlet was due to the readvance of the Lake Michigan Glacier

[a] Op. cit., p. 441.

southward to the latitude of Milwaukee. It appears to make little essential difference in the interpretation of the phenomena of this area whether the glacial deposition of the red clay be regarded as occurring before or after the interval of emergence which preceded the Calumet stage. The evidence on this point is thus far not decisive. At whatever stage this readvance and deposition of this clay occurred, lacustrine conditions south of the latitude of Milwaukee were correlated with the glaciation north of this latitude. On the retreat of the glacier the lake again extended itself northward.

The Calumet stage of Lake Chicago received its name from Mr. Leverett because of the relations of Calumet River, in Cook County, Ill., to the shore line. During the Glenwood stage the discharge through the Chicago outlet had cut down the barrier so that at the Calumet stage there was formed a shore line which now stands 35 or 40 feet above the level of Lake Michigan. The Calumet shore line is well developed all about the south end of the lake basin. It has been cut away between Evanston and Waukegan, Ill., but, extending northward from Waukegan to a point about 4 miles north of Racine, Wis., there is an ancient beach at the same elevation as that south of Evanston Ill. (Pl. XIV). Through Kenosha County the distance of this old shore line from the present beach varies from a few rods to nearly a mile. In Racine County, excepting where it cuts across Wind Point, the old beach deposits lie at the crest of the present lake bluff (Pl. IX, *B*). From a point 1½ miles northwest of Wind Point light-house nearly 50 miles to the north so great has been the encroachment of the lake upon the land that no trace of the old shore line remains.

POSSIBLE SECOND LOW-WATER STAGE.

Reference has already been made to the evidence of a low stage of water which Mr. Leverett[a] found at Holland, Mich. This evidence consists of an abandoned valley leading from Grand Rapids to Holland, Mich., at a depth at least 30 feet lower than the present lake level. This channel was formed subsequent to the formation of a beach which now stands upon a flat 30 to 40 feet above the lake, and prior to a lower beach which is now 25 feet above the lake. If the higher beach ridge, which is built up to 60 to 65 feet above the lake, is the Calumet beach, the emergence must have occurred between the Calumet and the Toleston stages.

Records of test borings on file in the office of the city engineer at Milwaukee show the presence of marsh deposits in the lower courses of Milwaukee and Menominee rivers at Milwaukee, extending about 50 feet below the level of

[a] Op. cit., p. 446.

the lake. These indicate that at some stage, when the lake waters had withdrawn approximately 50 feet below their present level, the valleys were cut down to that level. A refilling of the lake basin flooded the lower parts of the valleys and caused them to be filled with marsh and lake deposits. The fluctuation of the lake level indicated by this is commensurate with that shown by the channels on the east side of the lake. Unfortunately there seems to be nothing to indicate just at what time this emergence took place. It seems probable, however, that it did not occur prior to the deposition of the red clay.

The draining off of the waters at this stage, as before, was probably due to the opening of a northern outlet, either by a depression in that region or by the withdrawal of an obstructing glacier.

TOLESTON STAGE.

An obstruction of the northeast outlet again brought about a high-water stage and a resumption of the southwestward discharge through the Chicago outlet. The cutting down of this outlet had progressed so far that, at the Toleston stage, the lake developed its shore line but 20 to 25 feet above the present level of Lake Michigan. This third shore line, which takes its name from the village of Toleston, Ind., is well developed about the south end of the lake basin. Like the Calumet shore line, it has been destroyed between Evanston and Waukegan, Ill., but is yet preserved from Waukegan to Kenosha, Wis., where it is closely followed by the line of the Chicago and Northwestern Railway. From the State line to Kenosha it lies one-half to three-fourths of a mile from the present beach. North of Kenosha for nearly 60 miles it is entirely cut away except for some remnants of terraces in Milwaukee County.

LAKE MICHIGAN.

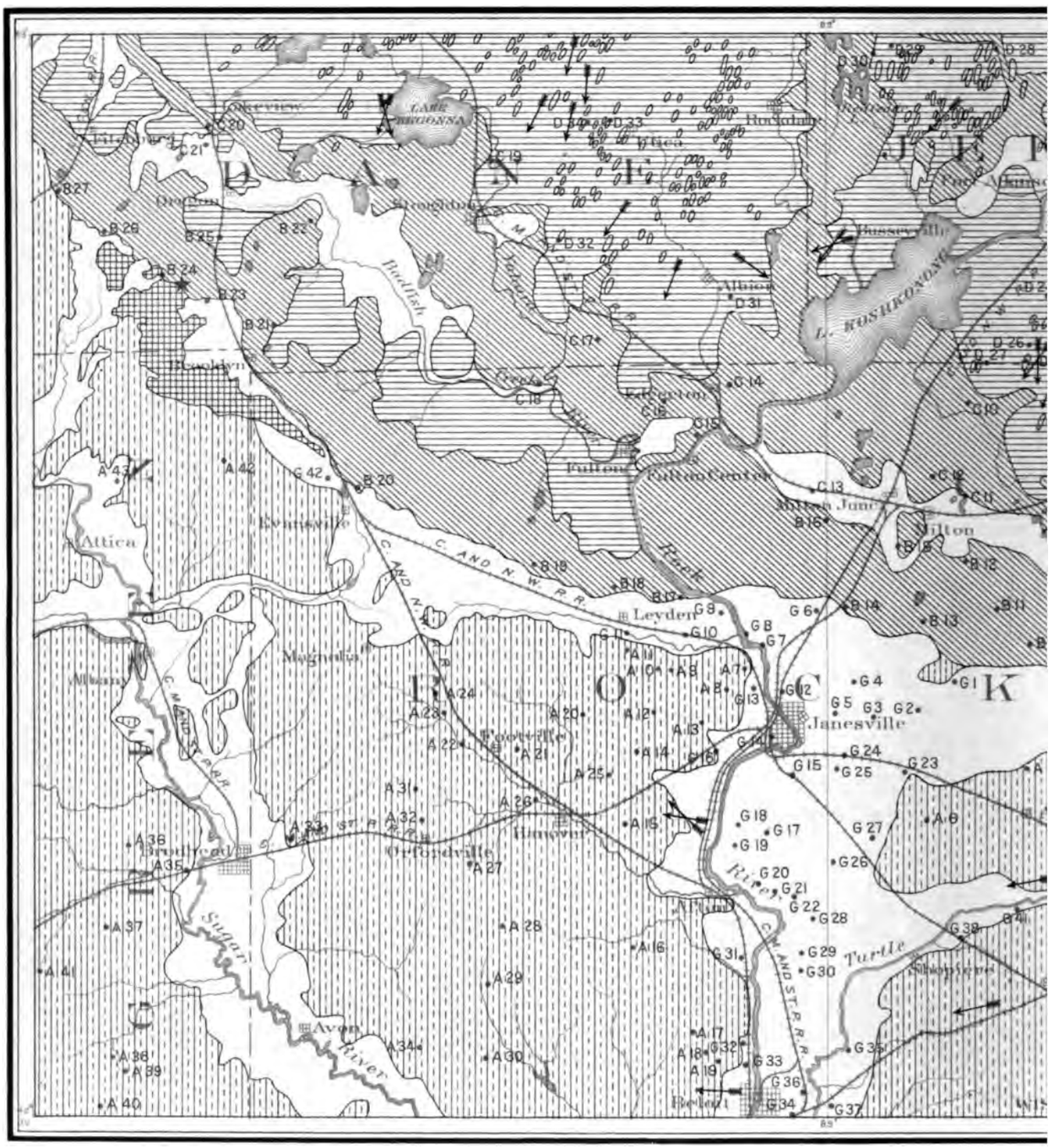
The final opening of the Straits of Mackinac and the consequent lowering of the lake level caused the abandonment of the Chicago outlet and the initiation of the present stage of the lake. The name "Lake Michigan" is applied to the lake from the final closing of the Chicago outlet to the present.

LITHOLOGICAL COMPOSITION OF THE DRIFT.

GENERAL STATEMENT.

In order to obtain a somewhat definite knowledge of the lithological composition of the glacial drift of southeastern Wisconsin, as a basis for deductions concerning the derivation, transportation, and deposition of the material composing the various glacial features, a large number of analyses of the drift of this region have been made. The data for these have been gathered during

U. S. GEOLOGICAL SURVEY



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several years of study, and embrace an area somewhat larger than that covered by the preceding discussion. It has been thought best, however, to put the results of this study into permanent form; and since most of these data have to do with the phenomena treated at length in the preceding discussion, it may be as well to incorporate the whole in this paper.

The data presented are the results of the examination of about 47,400 rock specimens collected at 266 places distributed over an area of about 2,940 square miles, embraced between parallels 42° 30′ and 43° north latitude and meridians 87° 45′ and 89° 30′ west longitude. This area, in southeastern Wisconsin, includes the whole of the counties of Racine, Kenosha, Walworth, and Rock; the southern parts of Milwaukee, Waukesha, and Jefferson counties; the southeastern part of Dane County, and the eastern part of Green County.

This area includes considerable tracts of pre-Wisconsin drift, the southern part of the area covered by the Green Bay Glacier, the area covered by the Delavan glacial lobe, and a part of the main Lake Michigan Glacier, and the attendant outwash deposits. The results of the analyses are shown in the accompanying tables, A–K, and the distribution of the places at which the analyses were made is shown on Pl. XV. Of these estimates, 43 were made in the pre-Wisconsin drift area, 42 in the outwash deposits bordering the Darien and Johnstown moraines, 27 in the Johnstown terminal moraine, 21 in the Milton terminal moraine, 12 in the interlobate Kettle moraine, 34 in the ground-moraine tract of the Green Bay Glacier, including the Hebron terminal moraine, and certain other morainal deposits, 29 in the Darien terminal moraine, 27 in the Elkhorn terminal moraine, 20 in the Valparaiso terminal moraine, 5 in the outwash deposit between the Darien and Elkhorn moraines, and 6 in the lake-border moraines of the Lake Michigan Glacier.

METHOD OF ANALYSIS.

In making these analyses, one to several hundred pebbles were taken indiscriminately from the drift at each of the places indicated; these were sorted with reference to the rock formations from which they were derived, and the percentages noted. Owing to the infrequent occurrence of fossils, the determinations were necessarily based on lithological characters. The characters of the several rock formations of the area are generally so distinctive as to be readily recognized by one familiar with them. There are, however, gradations from one type to another, so that discriminations can not always be made; thus, at best, the determinations can be considered as but rough approximations of the truth. Undoubtedly the judgment of different persons would differ considerably as to the identification of the rock specimens at any given locality. There would be

very little variance, however, in their judgment as to what was of local derivation and what was foreign to the area.

Further, the soft shales of the Cincinnati group, whose contribution was principally to the rock-flour matrix of the till, are entirely neglected in these estimates, and the friable sandstones of the St. Peter and Potsdam groups are probably not fully represented in the coarser material of the drift. Notwithstanding these limitations, the value of the results obtained is far from being vitiated. The remarkable agreement between the results obtained on the distribution of the local material and what would be expected from a priori consideration of the conditions of deposition, indicates more than a mere coincidence; and the still more remarkable agreement between the relative proportions of local and foreign material shown by the different tables seems to indicate that, taken in a large way, the results of the analyses must be very near a true exposition of the composition of the drift of the area. In consequence of the conditions of the determinations care must be taken not to press too far inferences based on mere local differences.

LOCAL AND FOREIGN MATERIAL IN THE DRIFT.

In considering the drift of any given part of this area, we may regard as foreign constituents all those rock fragments for which no parent formations are known within the limits of eastern Wisconsin in the path of the glacial movement which reached or crossed the tract in question. Thus, as will be seen by reference to Pl. I, in the area traversed by the Lake Michigan Glacier we may regard as foreign all the crystalline rocks, quartzites, and sandstones, and all the limestones and shales which can be identified as from formations below the Trenton group or above the Devonian. Excepting the area of the Delavan glacier lobe, the Trenton and Galena limestones and the Cincinnati shale, if they occurred, would also be excluded from the local material. As a matter of fact, the identifications by the writer have warranted only the classification of the crystalline rocks, the sandstones, and the quartzites as foreign material in the drift of the Lake Michigan Glacier.

In the drift of that part of the area traversed by the Green Bay Glacier lying within the district under discussion, all the Paleozoic material, limestones, sandstones, and shales, from the Potsdam to the Niagara, inclusive, may be of local derivation. The knobs of the Huronian quartzite in northwestern Jefferson County and southeastern Dodge County, in what is known as the Waterloo area, contributed much quartzite material, from which it is difficult to discriminate quartzite material which may be from more distant points, so that in the Green Bay drift only the crystalline rocks are regarded as certainly of foreign deriva-

tion. Certain crystalline knobs occur in eastern Wisconsin, but not in the track of the ice reaching the south end of the lobe.

So also in the pre-Wisconsin drift areas, only the crystalline rock material is regarded as surely of foreign derivation, inasmuch as a large part of the quartzite material there found has been regarded as derived from the Waterloo quartzite knobs.

If now we consider the 266 analyses presented in the accompanying tables with reference to the percentages of local and foreign material in the drift of the area under discussion, it is seen that the foreign material ranges from 3 to 32 per cent at the exposures examined, with the exception of one point where 50 per cent of foreign material was found. The average percentage of foreign material shown by all the analyses made is 12.93. That the variations are within narrow limits is shown by the following:

Résumé of analyses of drift materials.

Number of analyses.	Percentage of foreign material.
230	20
23	20 to 25
11	25 to 30
1	32
1	50
266	[a] 12.93

[a] Average.

If we consider the drift deposited by the several glaciers with reference to the percentages of local and foreign material, omitting the averages for the outwash deposits and the interlobate Kettle moraine, in all of which there was a mixture of drift from the Green Bay Glacier and the Delavan glacial lobe, the following results are obtained:

Amount of foreign material in drifts.

	Percentage of foreign material.
Pre-Wisconsin drift	11.55
Drift of Green Bay Glacier	10.73
Drift of Lake Michigan Glacier, including the Delavan glacial lobe	15.55

Taking the averages of the terminal moraines, we find the following percentages:

Amount of foreign material from Green Bay Glacier.

	Percentage of foreign material.
Johnstown moraine	10.03
Milton moraine	10.53
Average of 48 analyses	10.248

Amount of foreign material from Lake Michigan Glacier.

	Percentage of foreign material.
Darien moraine	15.74
Elkhorn moraine	17.46
Valparaiso moraine	13.259
Average of 76 analyses	15.698

If we omit the sandstones and quartzites from the foreign material of the Lake Michigan drift, taking only the crystalline rocks, as in the Green Bay drift, the difference stands as follows:

Comparative amounts of foreign crystalline material from Green Bay and Lake Michigan glaciers.

	Percentage of foreign crystalline rocks.
Green Bay Glacier moraines	10.248
Lake Michigan Glacier moraines	14.904

There appears to be no very notable difference between the ground moraine and the terminal moraines in the percentage of foreign material, as shown by the following:

Comparative amounts of foreign material from ground and terminal moraines.

	Percentage of foreign material.
Green Bay ground moraine	11.42
Johnstown terminal moraine	10.03
Milton terminal moraine	10.53

In the interlobate Kettle moraine, the Heart Prairie outwash deposits bordering both the Elkhorn and the Milton moraines, and the outwash deposits bordering both the Darien and the Johnstown moraines, in all of which the drift of the Green Bay and Lake Michigan glaciers is commingled, the drift is of an intermediate character, as shown by the following:

Amounts of foreign material in commingled drift from Green Bay and Lake Michigan glaciers

	Percentage of foreign material.
Interlobate Kettle moraine	15.99
Heart Prairie outwash deposit	11.71
Darien-Johnstown outwash deposit	12.78
Average of 59 analyses	13.34

A notable evidence of the thorough commingling of the local and foreign material during the transportation and deposition is found in the fact that in not one of the analyses of the material taken at random from these 266 exposures is crystalline material absent.

In considering the transportation of these erratics it should be noted that in all probability not a little of this foreign material was carried well on its way

southward by the glaciers of the earlier stages, and was picked up and carried onward during the later advances. Thus, if the facts were known it might be found that a considerable part of what is here called foreign material in the later drift sheets was picked up from the earlier drift at no great distance from the place of final deposition.

ENGLACIAL AND SUBGLACIAL DRIFT.

On the final melting of a glacier the englacial and superglacial drift is left commingled with the upper part of the subglacial drift or upon its surface. It is doubtful if englacial and superglacial till can be successfully distinguished from subglacial till after deposition has taken place. Being carried higher up in the ice, it would presumably be carried farther before it was deposited, so that the englacial drift at any given place might reasonably be expected to show a higher percentage of foreign material than that which was of subglacial origin. None of the material examined for analyses was found more than 30 or 40 feet below the surface, and most of it was from surface exposures or excavations but a few feet in depth. It represents ground moraine, terminal moraine, and outwash deposits, drumlins, kames, and esker-like ridges; yet nowhere has the writer seen any evidence of distinct englacial or superglacial till. The prevalent low percentages of foreign material, and high percentages of material which may have been derived from formations at comparatively short distances from the places of deposition, are just what would be expected in subglacial till. In more than 86 per cent of the analyses, material which might have been derived not more than 50 or 75 miles from the places of deposition constitutes 80 per cent or more of the drift.

There is, however, a certain part of the drift which appears to be very largely of englacial origin. This is the deposit of bowlders upon the surface of the drift sheet. Within the limits of the bowlder fans leading out from the Waterloo quartzite knobs in the area of the Green Bay Glacier, the local material forms a high percentage of the surface bowlder deposit. At many places there are bowlders of the local limestones, but they are generally few in number. There is a very much scattered train of bowlders of coarse, granular limestone, resembling that found in the ancient reefs of the Niagara formation, in the vicinity of Wauwatosa. This train may be traced southwestward from the vicinity of Wauwatosa for some distance, and the blocks were not improbably derived from the rock in this locality. Taken as a whole, however, the amount of local material in the surface bowlder deposit is very small. Accurate determination of percentages has not been made, but tne distribution of the deposit has been mapped in considerable detail, and the character of the bowlders has been carefully observed.

The writer confidently asserts that, excluding the quarzite bowlder fans, less than 10 per cent of the hundreds of thousands of bowlders scattered over the area are of other than foreign crystalline rocks. With these, at a few places, is considerable brown sandstone, probably from the Potsdam group of the Lake Superior region. It thus appears that the percentages of local and foreign material in the drift sheet and in the bowlder deposit upon its surface stand almost in inverse ratio. This bowlder deposit, lying as it does upon the surface of the drift sheet, and being composed so largely of material entirely foreign to the southeastern part of the State, seems clearly to be englacial drift. So far as the writer's observations have gone, this is the only part of the drift deposit which can with any certainty be regarded as of other than subglacial origin.

Noticeable among the surface erratics of the pre-Wisconsin drift area, because of the striking color which renders their identification easy, are bowlders of red quartz-porphyry. These are especially frequent in the older drift area east of Rock River. Though present in the later drift, they are much less frequently seen than in the older drift. These are believed to have been derived from the pre-Cambrian formations north of Lake Huron, whence they were brought to this area by the southwesterly movement of the earlier glaciers.

DISTRIBUTION OF THE LOCAL MATERIAL OF THE DRIFT.

PRE-WISCONSIN DRIFT.

In considering the distribution of the local material of the drift, frequent reference should be made to the accompanying tables of analyses, to Pl. XV, showing the distribution of these analyses, and to Pl. I, which shows the relations of the late Wisconsin glaciers to the geological structure of the eastern part of the State.

A glance at Table A shows how general is the presence of local material of easterly derivation (that from the Niagara limestone) in the pre-Wisconsin drift. This is represented especially by the Niagara limestone, which is sometimes present in considerable amounts, even west of Sugar River, in the towns of Decatur, Spring Grove, and Jefferson, in Green County.

This evidence of westerly or southwesterly movement of the earlier glaciers is in consonance with that afforded by striæ observed in the vicinity of Janesville and Beloit, and with the striæ and drumloidal ridges found in the older drift area east of Rock River.

The largest single element of this drift is from the Trenton group, as would be expected from its wide distribution in the area of the older drift. The Galena and Trenton together constitute more than 50 per cent of the material examined.

The subject of the derivation and distribution of the quartzite drift of the

pre-Wisconsin area requires an extended discussion and the consideration of questions which have not been fully solved, so that it has been thought best to leave this very interesting and important element entirely out of the present discussion. The same omission is made in regard to the quartzite bowlder trains of the Green Bay Glacier. This subject has been discussed by Mr. Ira M. Buell, in a paper before the Wisconsin Academy of Science, Arts, and Letters.[a]

DRIFT OF THE GREEN BAY GLACIER.

The direction of the axial movement in the Green Bay Glacier and of the lines of deployment in the southern end of the lobe, as shown by the drumlins and striæ, was in general parallel to the strike of the Paleozoic formations which were overridden (Pl. I). In consequence of this, the local drift material is distributed in more or less clearly marked belts, corresponding in arrangement to that of the underlying rock formations. Since the lines of flowage did not correspond exactly to the trend of the outcropping belts of the several formations, and since the area appears to have been traversed by an earlier glacial movement of more southwestward trend, there is considerable mixing of the local material throughout the several belts. Nevertheless, it is remarkable how quickly and distinctly the passage from one of these Paleozoic belts to that of a higher or lower formation manifests itself by a change in the composition of the drift. This change in the character of the drift in passing across the Green Bay drift from east to west is readily seen from an inspection of Tables B, C, D, and E. These tables show the composition of the drift of the Johnstown terminal moraine, the Milton terminal moraine, the ground moraine of the Green Bay Glacier, and the interlobate Kettle moraine, respectively. As will be seen from the index map, Pl. XV, the analyses are arranged in the several tables in the order of their location from east to west.

In the Kettle moraine (Table E), where it lies close to or upon the west margin of the Niagara formation, the predominant constituent is Niagara limestone. Though not shown in this table, material from the Cincinnati shale is also abundant in some parts of this moraine. The Galena and Trenton limestones, not discriminated here, form a large part of the drift contributed by the Green Bay Glacier. Westward along the Johnstown moraine (Table B), the Niagara constituent decreases until it almost disappears on crossing Rock River in the town of Janesville. In the Milton moraine (Table C) it does not appear in the estimates west of the town of Lima. In the ground moraine (Table D) Niagara limestone is the principal constituent in the towns of Ottawa, Eagle,

[a] Buell, Ira M., Bowlder trains from the outcrops of the Waterloo quartzite area: Trans. Wisconsin Acad. Sci., Arts, and Let., vol. 10, 1895, pp. 485–509.

Sullivan, and Palmyra, though the Galena and Trenton limestones are not shown separately in the table. So large is the Niagara ingredient as to give rise to a suggestion that the front of the Lake Michigan Glacier might have advanced farther west than the line of the Kettle moraine before the Green Bay Glacier had fully developed. It seems more probable, however, that a part of this westerly distribution was due to the earlier advances of the ice, or it may be that this material was derived farther north, where the Niagara formation has a more westerly extension. (See Pl. I, p. 12.)

As the Niagara constituent decreases on going westward, the Galena limestone increases, becoming the predominant element until the zone is reached where the Trenton limestone is exposed by erosion in the pre-Glacial Rock River Valley and its tributaries in the towns of Jefferson, Koshkonong, Milton, and Harmony.

The Trenton limestone is generally the largest ingredient of the drift in the region west of the pre-Glacial Rock River Valley. The Lower Magnesian limestone does not become a recognizable constituent until the region of its exposure in the pre-Glacial Yahara or Catfish basin of southern Dane County is reached.

The sandstone element, though generally present, is probably not accurately shown in the tables. Owing to the friable character of the sandstones, as has been stated, their contribution was generally more to the finer material of the drift than to the coarser material from which the analyses shown in the tables were made. The prevalent character of the finer material of the till is that of a rock flour derived from the abrasion of limestones and shales.

On passing westward from Rock River the increased contribution from the sandstone formation is evident in the more arenaceous character of the drift. With the increase of arenaceous material the till becomes less compact and the effects of leaching and oxidation extend to greater depths. The more compact till of the limestone districts is rarely leached of its lime carbonate to greater depths than 1 or 2 feet, while the effects of oxidation are manifest only in the change of the color of the upper part of the till from bluish gray to light buff. In the more arenaceous parts the carbonates may be removed to depths of 3 to 5 feet, or even more, while the color of the upper part of the drift has been changed from buff to brownish, and the buff color extends to greater depths. This difference is worthy of note, especially in making comparisons of the evidences of age in the earlier and the later drift sheets. In the discussion of the pre-Wisconsin drift east of Rock River it was stated that this drift was thoroughly leached of its calcareous elements to a depth of 3 or 4 feet, sometimes to a depth of 5 feet or more, while oxidation had stained the upper 3 or 4 feet to a brownish or a yellowish brown color. Even so far west as the margin of the drift area, near Monroe, in Green County, the depths of leaching noted in

clayey till were generally not more than 3 or 4 feet, and nowhere more than 7 feet.

It is thus apparent that it is important to note the composition and texture of the drift when drawing inferences as to the relative age of the drift sheets from the amount of leaching and oxidation accomplished.

The percentages of Huronian quartzite shown in the Tables B, C, and D are not to be taken as a true exposition of the quartzite content of the drift within the quartzite bowlder fans. A large number of estimates of this quartzite content were made by Mr. Ira M. Buell during his study of the bowlder fans derived from the Waterloo outcrops. Several other estimates were made by the writer in northern Rock County and eastern Dane County, but as these were to determine the actual amounts of quartzite material rather than the percentages of the different rock constituents of the drift, they have been omitted from the tables. As has been stated, the full discussion of the quartzite drift is not taken up in this paper.

DRIFT OF THE DELAVAN LOBE AND OF THE MAIN LAKE MICHIGAN GLACIER.

Passing now to the consideration of the drift of the Delavan lobe and the main Lake Michigan Glacier, as shown in Tables H, I, J, and K, we see that the composition is considerably different from that of the Green Bay Glacier. The Niagara limestone is everywhere the predominant constituent of the drift. Material derived from the lower horizons of the Paleozoic formations is present in notable amount only in those parts of the Elkhorn and Darien moraines which lie across the pre-Glacial Troy Valley, in whose slopes the Cincinnati shales, the Galena limestone, and probably also the Trenton limestone were exposed. The Niagara constituent stands as follows:

Niagara limestone in the drift of the Lake Michigan Glacier.

	Per cent.
Darien moraine of Delavan lobe	60.69
Elkhorn moraine of Delavan lobe	64.05
Valparaiso moraine of Lake Michigan Glacier	86.724
Lake-border morainic system of Lake Michigan Glacier	76.63
Averages of 82 analyses	69.31

The difference between the drift of the Delavan lobe and that of the Green Bay Glacier begins to show itself in the interlobate deposit northeast of Richmond, as will be seen by comparing Tables B and H. Analyses 1–6, Table B, were made on the Green Bay side of this deposit. Analyses 1–9, Table H, were made on the Delavan side of the same deposit. Though there was doubtless considerable mixing

of the drift of the two glaciers in this tract, yet the analyses show a marked difference in the percentages of Niagara limestone.

That the Galena and Trenton limestones should appear in so large percentages as they do in more than 40 different analyses of the drift of the Darien and Elkhorn moraines seems remarkable, considering the limited extent of the exposure of these formations within the area of the Delavan lobe, and considering that the material examined was taken at the surface of the drift, 100 to several hundred feet higher than the levels at which the rock formations were exposed to glacial action. The average percentages of Galena and Trenton limestone in those parts of the Darien and Elkhorn moraines lying across the pre-Glacial Troy Valley northwest of Lake Geneva are as follows:

Average amounts of Galena and Trenton limestones in parts of Darien and Elkhorn moraines.

	Per cent.
Darien moraine	25.10
Elkhorn moraine	18.54

It seems hardly possible, however, to ascribe all the amounts shown in the 42 analyses to errors in identification, or to a mixing of the drift of the Green Bay Glacier with that of the Delavan lobe. Each of these factors may enter into the results shown, but there still remains evidence that considerable material was derived from the Galena and Trenton formations exposed in Troy Valley and brought to a position for deposition in the upper part of the moraines within a few miles of the limit of the advance. It is, of course, possible that this material was picked up by the earlier glaciers and was taken from earlier drift by the Delavan lobe and redeposited.

Following the Darien and Elkhorn moraines eastward about Lake Geneva, into the Niagara province, through the towns of Walworth, Linn, Bloomfield, Geneva, Lyons, and Burlington, the Galena and Trenton constituents disappear from the analyses and the contribution from the Niagara group becomes generally 70 to 90 per cent.

In the material examined from the Valparaiso morainic system (Table J) the Niagara constituent does not fall below 82 per cent.

A part of this Niagara constituent, which is clearly very local in its derivation, consists of fragments of red argillaceous limestone. The only exposures of these red beds in situ is in a quarry 1 mile southwest of Burlington, but their presence in the lower part of the Niagara formation in western Racine and Kenosha counties is shown by numerous wells. This red material is generally present in the drift of western Racine and Kenosha counties and in eastern Walworth County. Analyses within the western half of the Niagara province frequently show 1 to 3 or more per cent of this material.

The drift in the lake-border belt (Table K) contains, in addition to the Niagara material, thin-laminated, brittle limestone from deposits exposed near Milwaukee, referred to the Salina formation, and fragments of the hydraulic limestones and blue and black shales of the Hamilton group which occur in the same vicinity.

OUTWASH DEPOSITS.

It has already been noted that the drift of the outwash deposit associated with the formation of the Darien and Johnstown moraines is intermediate in character between that of the moraines which it borders in regard to the percentages of foreign material. This is a consequence of the intermingling of the detritus-bearing waters from the Delavan and Green Bay ice fronts.

The results of this commingling are even more plainly seen in the distribution of the local constituents. Table G shows the analyses of the drift of this outwash deposit. It will be seen by referring to this table that the Niagara material is very generally distributed through the deposit, being shown by all the analyses except the one made in the town of Union, the most northwesterly township of Rock County. The Niagara constituent, however, nowhere reaches 20 per cent, except in those parts which received the discharge directly from the front of the Delavan lobe, as shown by analyses 39 and 40, Table G, or in those parts of Bradford, La Prairie, Turtle, Rock, and Beloit townships which were reached by the Darien waters from this lobe passing through the Turtle Creek gorge, in southern Bradford Township. (See analyses 22, 28, 29, 30, 32, and 34–41.) As has been previously noted, the larger percentages of Niagara material in these parts is one evidence that outwash material from the Darien moraine was actually carried through the rock gorge by the escaping waters.

The predominant constituent of the coarser outwash drift, as would be expected, is Trenton limestone, with which is considerable drift showing the characteristics of the Galena limestone. Sandstone pebbles are generally present, as is also a large ingredient of loose quartz sand. In some parts the deposit is mostly sand. Quartzite pebbles are generally distributed, though in small amounts.

Table F shows a few analyses of the outwash deposits formed behind the Darien moraine which border the Elkhorn and Milton moraines near their point of junction. As has been stated, the disposition of this deposit indicates that the outwash was principally from the Green Bay Glacier. The percentages of Niagara limestone shown in Table F are intermediate between the low percentages of Niagara material in the Milton moraine in Whitewater Township and the high percentages of material from the same formation in the Elkhorn moraine. This indicates a mixture of drift of the Delavan lobe and of the Green Bay Glacier

by the waters from the interlobate angle near Lagrange and from the contiguous ice fronts.

LESS COMMON CONSTITUENTS OF THE DRIFT.

COPPER, IRON, MARCASITE, AND DIAMONDS.

Among the less common of the foreign ingredients in the drift of this area are pieces of metallic copper from the Lake Superior regions. These specimens, popularly known as "float copper" or "drift copper," are found not infrequently, though they are by no means abundant. They vary from a few ounces to several hundred pounds in weight. A farmer living near the village of Caldwell Prairie, in northwestern Racine County, informed the writer that he had at one time plowed up on his land a piece of float copper weighing over 500 pounds.

Occasional pebbles of ferruginous sandstone and other iron ores occur within and upon the surface of the drift.

The writer has found a few nodules of marcasite in the drift near Milwaukee. These have a radiating crystalline structure.

Foreign elements of great interest as well as of rare occurrence in the drift are the diamonds which have been found at several places in southeastern Wisconsin. Three of these stones were found within the area under discussion. The first was found in or near the village of Eagle, in southwestern Waukesha County, in 1876; another, on the farm of Judson Devine, 2½ miles southwest of the village of Oregon, in Dane County, in October, 1893; while a third was found near Burlington, Racine County, at a time which has not been ascertained.

These, as well as other diamonds found in the glacial drift of the region of the Great Lakes, have been described, and their mode of occurrence discussed, by Prof. William H. Hobbs.[a] Professor Hobbs gives a probable explanation of the diamond distribution, and discusses the subject of a probable source of derivation east of James Bay, with references to other publications. The accompanying data concerning the Eagle, Oregon, and Burlington stones are from this article by Professor Hobbs:

[a] Hobbs, Wm. H., The diamond field of the Great Lakes: Jour. Geol., vol. 7, 1899, pp. 375–388.

The occurrence of the three stones found in the area under discussion was as follows: The Oregon diamond was found about one-half mile inside the outer margin of the outer or Johnstown terminal moraine of the Green Bay Glacier, at a point about 3 miles northwest of the northwest corner of Rock County, where the moraine enters Dane County from the southeast. The Eagle diamond was found in the interlobate Kettle moraine, or the closely bordering outwash deposits of the upper terrace, in or near the village of Eagle, in southwestern Waukesha County. The exact location of the Burlington find is not known, although the stone is believed to have come from the terminal-moraine deposits of the Lake Michigan Glacier or of the Delavan lobe of the same in the vicinity of Burlington. The approximate locations are shown on Pl. XV. These, like all the other drift diamonds of the region of the Great Lakes, occur in the terminal moraines of the late Wisconsin glaciers or in the attendant outwash deposits.

Professor Hobbs states that of the seventeen diamonds which have been found in the glacial drift of the Great Lakes region, three of the stones (including the two of largest size) remained in the hands of the farming population without their nature being discovered for periods of eight and one-half, seven, and more than fifteen years, respectively, so that it is not at all improbable that others now lie in the little collections of "pretty stones" and local curios which adorn the clock shelves of the country farm houses. Doubtless also many others still lie buried in the drift. That they are, however, of infrequent occurrence may be inferred from the writer's own experience. He has not discovered a single diamond in several seasons' examination of the drift in all of its aspects within the area. He has not, however, made a special search for them.

SUMMARY.

In conclusion, a few of the salient features of this discussion of the lithological composition of the drift of this part of southeastern Wisconsin may be pointed out.

The drift of the area is predominantly of local character, some of it apparently having its place of derivation within a few miles of the place of final deposition. This local material constitutes about 87 per cent of the material examined.

About 13 per cent of the material examined must have traveled several hundred miles to reach its destination. Some of the foreign material may have made part of the journey at earlier stages of glaciation.

The relative amounts of local and foreign material in the body of the drift and in the bowlder deposit on its surface stand in almost inverse ratio, the surface bowlders being predominantly foreign. From this fact, and from their

TABLES SHOWING LITHOLOGICAL COMPOSITION OF THE DRIFT OF A PORTION OF SOUTHEASTERN WISCONSIN.

TABLE A.—*Pre-Wisconsin drift.*

Number of analysis	1	2	3	4	5	6	7	8	9	10	11	12	13
Town	Sharon (T. 1 N., R. 15 E.).		Darien (T. 2 N., R. 15 E.).	Clinton (T. 1 N., R. 14 E.).	Bradford (T. 2 N., R. 14 E.).	La Prairie (T. 2 N., R. 13 E.).	Janesville (T. 3 N., R. 12 E.).						
Section	25	6	32	4	5	15	23	27	21	20	18	29	33
Fraction	SE. ¼	SW. ¼	SE. ¼	SE. ¼	SW. ¼	E. ½	.....	.....	.....	.....	.....	.....	.....
Niagara limestone	} 82½	62½	}	} 97	29	11	9	35	13	15	26	82	19
Galena limestone					56	15	.....	1	1	.....	.....	.....	7
Trenton limestone		16½	75		.....	40	52	40	65	67	55	9	57
Lower Magnesian limestone (including Mendota limestone)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
St. Peter and Potsdam sandstone	½	2½	3	.....	.....	5	5	5	.....	3	.....	.....	4
Huronian quartzite	½	.....	.....	.....	.....	.....	.....	.....	1	.....	1	1	2
Archean crystalline rocks	13½	18½	22	3	15	15	19	11	18	8	8	6	6
Chert and quartz	2½	.....	.....	.....	.....	8	3	.....	2	2	4	.....	2
Doubtful, mostly limestone	.....	.....	.....	.....	.....	6	12	8	.....	5	6	2	3
Proof	100	100	100	100	100	100	100	100	100	100	100	100	100
Percentage of foreign material	13½	18½	22	3	15	15	19	11	18	8	8	6	6

Number of analysis	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Town	Rock (T. 2 N., R. 12 E.).		Beloit (T. 1 N., R. 12 E.).				Center (T. 3 N., R. 11 E.).					Plymouth (T. 2 N., R. 11 E.).			
Section	6	18	5	21	28	27	25	33	31	30	30	1	10	20	33
Fraction	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	NW.	.....	.....	.....	.....
Niagara limestone	32	4	27	22	26	33½	22	23	13	22	27	19	14	15	15
Galena limestone	.....	3	11	9	9	14½	.....	.....	.....	.....	4	1	.....	10	2
Trenton limestone	53	54	48	47	50	34	50	53	42	46	44	64	48	53	64
Lower Magnesian limestone (including Mendota limestone)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
St. Peter and Potsdam sandstone	.....	6	1	5	1	1½	1	1	9	3	2	.....	3	3	2
Huronian quartzite	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	.....
Archean crystalline rocks	12	12	5	14	7	7½	17	12	13	11	6	3	15	9	7
Chert and quartz	.....	14	1	1	.....	.....	2	.....	.....	.....	3	3	7	3	2
Doubtful, mostly limestone	3	6	7	2	7	9	8	11	23	18	14	10	13	5	8
Proof	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Percentage of foreign material	12	12	5	14	7	7½	17	12	13	11	6	3	15	9	7

TABLE A.—*Pre-Wisconsin drift*—Continued.

Number of analysis	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	
Town	Newark (T. 1 N., R. 11 E.).		Spring Valley (T. 2 N., R. 10 E.).			Avon (T. 1 N., R. 10 E.).	Decatur (T. 2 N., R. 9 E.).		Spring Grove (T. 1 N., R. 9 E.).				Jefferson (T. 1 N., R. 8 E.).	Brooklyn (T. 4 N., R. 9 E.).		Averages (Niagara, Galena, and Trenton approximate).
Section	8	29	12	13	17	24	26	21	5	29	28	32	12	24	21	
Fraction																
Niagara limestone	1	.....	5	7	17	17	29	4	29	25	10	.....	62	7	23	21.30
Galena limestone	.....	.....	2	.....	1	.....	.....	.....	.....	8	29	2	.....	.....	5	3.63
Trenton limestone	82	28	62	64	61	69	32	61	15	30	52	56	8	21	43	48.59
Lower Magnesian limestone (including Mendota limestone)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
St. Peter and Potsdam sandstone	1	3	4	6	1	.....	2	14	3	.....	.....	2	.....	9	.....	2.58
Huronian quartzite	.....	.....	.....	.....	.....	1	3	.....	.....	2	1	.....	.....	6	1	.529
Archean crystalline rocks	4	18	14	10	3	8	14	9	13	3	4	7	6	50	21	11.55
Chert and quartz	1	2	2	7	1	1	6	5	2	.....	1	4	2	5	.....	2.29
Doubtful, mostly limestone	10	49	11	6	16	4	14	7	38	32	3	29	22	2	7	10.09
Proof	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100.559
Percentage of foreign material	4	18	14	10	3	8	14	9	13	3	4	7	6	50	21	11.55

TABLE B.—*Johnstown terminal moraine of the Green Bay Glacier.*

Number of analysis	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Town	White water (T. 4 N., R. 15 E.).	Richmond (T. 3 N., R. 15 E.).						Johnstown (T. 3 N., R. 14 E.).				Harmony (T. 3 N., R. 13 E.).		
Section	25	35	3	9	17	17	7	11	22	17	7	1	15	8
Fraction	SW. ¼	SE. ¼	S. ½	SE. ¼	N. ½	S. ½	NE. ¼	SE. ¼	Mid.	SW. ¼	SW. ¼	NW. ¼	NE. ¼	SW. ¼
Niagara limestone	28	55	35	2	12	5	5½	7	2	3	6	9	6	8
Galena limestone	35	.....	36	69	70	73½	81½	69	90½	77	79	67	63	10
Trenton limestone	24	25	10	.....	4	10½	6	11		2	5	9	15	72
Lower Magnesian limestone (including Mendota limestone)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
St. Peter and Potsdam sandstone	2	.....	2	1	1	½	½	2	.....	3	1	1	1	2
Huronian quartzite	.....	.....	3	.....	.....	½	½	2	.....	.....	.....	.....	1	1
Archean crystalline rocks	11	20	8	16	13	5½	5½	6	7	11	9	11	12	7
Chert and quartz	.....	.....	5	3	.....	½	½	2	½	4	.....	1	2	.....
Doubtful, mostly limestone	.....	.....	1	9	.....	4	.....	1	.....	.....	.....	2	.....	.....
Proof	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Percentage of foreign material	11	20	8	16	13	5½	5½	6	7	11	9	11	12	7

TABLE B.—*Johnstown terminal moraine of the Green Bay Glacier*—Continued.

Number of analysis	15	16	17	18	19	20	21	22	23	24	25	26	27	Averages (Galena, Trenton, and Lower Magnesian approximate).
Town	Milton (T. 4 N., R. 13 E.).		Janesville (T. 3 N., R. 12 E.).	Center (T. 3 N., R. 11 E.).		Union (T. 4 N., R. 10 E.).	Rutland (T. 5 N., R. 10 E.).	Oregon (T. 5 N., R. 9 E.).					Montrose (T. 5 N., R. 8 E.).	
Section	33	30	9	12	4	22	30	4	25	22	13	8	1	
Fraction	SE. ¼	SE. ¼	.....	.....	NW. ¼	SW. ¼	NE. ¼	SW. ¼	NW. ¼	W. ½	NW. ¼	S. ½	.....	
Niagara limestone	13	13	8	2	.....	3	.....	.....	.....	1	.....	2	....	8.33
Galena limestone	39	25	2	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	30.69
Trenton limestone	25	43	58	32	65	56	29	75	34	66	37	29	61	29.01
Lower Magnesian limestone (including Mendota limestone)	.....	.....	.....	.....	6	20	28		20	13	25	35	12	6.11
St. Peter and Potsdam sandstone	5	6	1	4	9	11	39	17	36	12	20	22	7	7.629
Huronian quartzite	1	.....	5	9	3	1	2	.....	1	.....	1	1	....	1.85–
Archean crystalline rocks	15	11	20	9	12	6	2	8	7	8	14	11	6	10.03
Chert and quartz	.....	.....	6	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.944+
Doubtful, mostly limestone	2	2	.....	40	5	3	.....	.....	2	.....	3	.....	14	3.25–
Proof	100	100	100	100	100	100	100	100	100	100	100	100	100	97.363
Percentage of foreign material	15	11	20	9	12	6	2	8	7	8	14	11	6	10.03

TABLE C.—*Milton terminal moraine of the Green Bay Glacier.*

Number of analysis	1	2	3	4	5	6	7	8	9	10	11	12	13
Town	La Grange (T. 4 N., R. 16 E.).			Whitewater (T. 4 N., R. 15 E.).			Lima (T. 4 N., R. 14 E.).			Milton (T. 4 N., R. 13 E.).			
Section	9	18	18	24	26	32	14	14	22	12	25	23	30
Fraction	SW. ¼	SE. ¼	Mid.	W. ½	NW. ¼	SE. ¼	NE. ¼	SE. ¼	SE. ¼	NW. ¼	NW. ¼	W. ½	NW. ¼
Niagara limestone	29½	25	20	7½	6	6	7	10½	7	.....	.....	.....	.....
Galena limestone	57½	63	67	43	63	67	70	70½	80	43	45	55	25
Trenton limestone				22	22	10	10	4	2	39	19	26	43
Lower Magnesian limestone (including Mendota limestone)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
St. Peter and Potsdam sandstone	1	1	3	5½	2	2	1	1½	1	3	1	4	6
Huronian quartzite	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	1	.....
Archean crystalline rocks	12	11	9	21	7	15	11	13½	10	11	15	12	11
Chert and quartz	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	2	2	2
Doubtful, mostly limestone	.....	1	1	1	.....	.....	1	.....	.....	2	18	.....	13
Proof	100	100	100	100	100	100	100	100	100	100	100	100	100
Percentage of foreign material	12	11	9	21	7	15	11	13½	10	11	15	12	11

TABLE C.—*Milton terminal moraine of the Green Bay Glacier*—Continued.

Number of analysis	14	15	16	17	18	19	20	21	
Town	Fulton (T. 4 N., R. 12 E.).			Dunkirk (T. 5 N., R. 11 E.).	Porter (T. 4 N., R. 11 E.).	Pleasant Sp. (T. 6 N., R. 11 E.).	Fitchburg (T. 6 N., R. 9 E.).		Average (Galena, Trenton, and Lower Magnesian approximate).
Section	3	16	5	36	3	32	26	35	
Fraction	NW. ¼	NW. ¼	SW. ¼	NW. ¼	SW. ¼	NE. ¼	SE. ¼	.....	
Niagara limestone	.....	.....	.....	.....	.....	.....	.....	.....	5.64
Galena limestone	.....	.....	.....	.....	.....	.....	.....	.....	37.43
Trenton limestone	85½	90	79	76	79	85	.....	31	29.55
Lower Magnesian limestone (including Mendota limestone)	....	.....	.....	3	.....	.....	57	42	2.14
St. Peter and Potsdam sandstone	3½	.....	4	3	5	4	21	20	4.39
Huronian quartzite	4	2	5	2	8	2	1	.....	1.24
Archean crystalline rocks	4½	5	9	13	3	6	15	7	10.53
Chert and quartz	2½	3	3	.....	5	2	5	.....	1.31
Doubtful, mostly limestone	.....	.....	.....	3	.....	1	1	.....	2.
Proof	100	100	100	100	100	100	100	100	94.23
Percentage of foreign material	4½	5	9	13	3	6	15	7	10.53

TABLE D.—*Ground moraine of the Green Bay Glacier.*

Number of analysis	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Town	Ottawa (T. 6 N., R. 17 E.)	Eagle (T. 5 N., R. 17 E.).		Sullivan (T. 6 N., R. 16 E.)	Palmyra (T. 5 N., R. 16 E.).			Hebron (T. 6 N., R. 15 E.).				Cold Spring (T. 5 N., R. 15 E.).	Whitewater (T. 4 N., R. 15 E.).	
Section	32	5	6	33	3	14	5	12	25	36	31	19	4	7
Fraction	SE. ¼	NE. ¼	SW. ¼	NE. ¼	NE. ¼	N. ½	SW. ¼	SE. ¼	E. ½	SE. ½	W. ½	NW. ½	NE. ¼	W. ½
Niagara limestone	81	84	82½	84	78	82	80½	.....	.....	.....	11	21½	5	4
Galena limestone	.....	.....	.....	.....	.....	.....	.....	79	89½	90	10	18½	56	44
Trenton limestone	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	25	44½	15	39
Lower Magnesian limestone (including Mendota limestone)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
St. Peter and Potsdam sandstone	.....	.....	1	2	.....	.....	3	.....	1	1	21	½	3	1
Huronian quartzite	.....	2	½	.....	.....	½	.....	1	.....	.....	.....	½	1	.....
Archean crystalline rocks	19	14	16	14	22	16	16½	20	9½	9	32	12½	11	12
Chert and quartz	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Doubtful, mostly limestone	.....	.....	.....	.....	.....	1½	.....	.....	.....	.....	1	2	9	.....
Proof	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Percentage of foreign material	19	14	16	14	22	16	16½	20	9½	9	32	12½	11	12

TABLE D.—*Ground moraine of the Green Bay Glacier*—Continued.

Number of analysis	15	16	17	18	19	20	21	22	23	24	25	26
Town	Lima (T. 4 N., R. 14 E.).		Koshkonong (T. 5 N., R. 14 E.).									
Section	2	3	36	13	10	22	22	27	34	20	32	32
Fraction	NE. ¼	SW. ¼	Mid	N. ½	SE. ¼	Mid	W. ½	SW. ¼	NW. ¼	SE. ¼	SW. ¼	NE. ¼
Niagara limestone	8	11	15	26	23	36	15	11	10	5	7	15
Galena limestone	59	49	51	4	12	15	39	27½	30	18	55	43
Trenton limestone	23	34	28	60	42	42	33	49	51	51	33	38
Lower Magnesian limestone (including Mendota limestone)												
St. Peter and Potsdam sandstone					5	1	3	1½		2		
Huronian quartzite							2	1				
Archean crystalline rocks	10	6	5	8	13	5	8	6½	9	8	5	4
Chert and quartz												
Doubtful, mostly limestone			1	2	1			3½		16		
Proof	100	100	100	100	100	100	100	100	100	100	100	100
Percentage of foreign material	10	6	5	8	13	5	8	6½	9	8	5	4

Number of analysis	27	28	29	30	31	32	33	34	
Town	T. 5 N., R. 13 E.	Jefferson (T. 6 N., R. 14 E.	Oakland (T. 6 N., R. 13 E.).		Albion (T. 5 N., R. 12 E.).	Dunkirk (T. 5 N., R. 11 E.).	Pleasant (T. 6 N., R. 11 E.).	Spring	Averages Niagara, Galena, and Trenton approximate).
Section	36	7	9	16	22	11	24	24	
Fraction	SE. ¼	SW. ¼	SE. ¼	NW. ¼	SW. ¼	SW. ¼	SW. ¼	SE. ¼	
Niagara limestone	14						½		11.11+
Galena limestone	24	33							25.51+
Trenton limestone	47	42	77	77	83½	85½	90	86½	48.61+
Lower Magnesian limestone (including Mendota limestone)					1½	3	2		.19
St. Peter and Potsdam sandstone	3	2	2		2½	3½	1½	2	1.83+
Huronian quartzite	2	1	2	6	4	1½	1	1	.82
Archean crystalline rocks	9	14	12	16	8	5½	5	8	11.42+
Chert and quartz	1			1	½	½		2	.11+
Doubtful, mostly limestone		8	7			½		½	1.56
Proof	100	100	100	100	100	100	100	100	101.16+
Percentage of foreign material	9	14	12	16	8	5½	5	8	11.42+

TABLE E.—*Interlobate Kettle moraine.*

Number of analysis	1	2	3	4	5	6	7	8	9	10	11	12	
Town	Genesee (T. 5 N., R. 18 E.).		Eagle (T. 5 N., R. 17 E.).					Palmyra (T. 5 N., R. 17 E.).					Averages.
Section	5	30	21	21	20	20	30	23	26	26	27	33	
Fraction	Mid.	NE. ¼	Mid.	SW. ¼	SE. ¼	SW. ¼	W. ½	SE. ¼	W. ½	SW. ¼	SW. ¼	SW. ¼	
Niagara limestone	80	78½	62	60	54	57	62	58	58½	43½	53½	43	59.13
Galena and Trenton limestone	.....	.....	13	18	23	20	12½	26	20	39½	23	26	18.40
Lower Magnesian limestone (including Mendota limestone)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
St. Peter and Potsdam sandstone	1½	1½	2	2	2	.....	5	2	1½	1½	2	15	3.00
Huronian quartzite	½	½	.....	.....	.....	.....	½	.....	.....	½	.....	.....	.16
Archean crystalline rocks	16½	19½	18½	20	18	17	14½	12½	15½	14½	13½	12	15.99
Chert and quartz	½	.....	.....	.....	1	.....	.....	1	1	.....	.....	.....	.316
Doubtful, mostly limestone	½	.....	4½	.....	2	6	5½	½	3½	1	8	4	2.98
Proof	100	100	100	100	100	100	100	100	100	100	100	100	99.98
Percentage of foreign material	16½	19½	18½	20	18	17	14½	12½	15½	14½	13½	12	15.99

TABLE F.—*Outwash deposits bordering the Elkhorn and Milton moraines near their point of junction.*

Number of analysis	1	2	3	4	5	
Town	Whitewater (T. 4 N., R. 15 E.).		Lagrange (T. 4 N., R. 16, E.).		Sugar Creek (T. 3 N., R. 16 E.).	Averages.
Section	24	25	20	21	5	
Fraction	SE. ¼	NE. ¼	SE. ¼	E. ½	W. ½	
Niagara limestone	8½	15½	32½	35	45	27.38
Galena limestone	67½	29½	42½	53	30	44.48
Trenton limestone	13½	38½	3	.....	6	12.28
Lower Magnesian limestone (including Mendota limestone)	.....	.....	.....	.....	.....	.....
St. Peter and Potsdam sandstone	1½	1½	4	2	2	2.16
Huronian quartzite	½	½	.....	.....	.....	.12
Archean crystalline rocks	5½	11½	16	10	16	11.71
Chert and quartz	.....	½	.....	.....	.....	.05
Doubtful, mostly limestone	3	3	2	.....	1	1.6
Proof	100	100	100	100	100	99.78
Percentage of foreign material	5½	11½	16	10	16	11.71

TABLE 6.—*Ontonish deposits bordering the Darien and Johnstown moraines.*

Number of analysis	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Town	Harmony (T. 3 N., R. 13 E.)							Janesville (T. 3 N., R. 12 E.)						
Section	26	27	32	29	31	7	14	14	15	16	19	25	26	35
Fraction	NE. ¼	S. ½	NW. ¼	N. ½	NE. ¼	S. ½	SE. ¼	SW. ¼	NE. ¼	SE. ¼	Mid.	SW. ¼	NE. ¼	SE. ¼
Niagara limestone	17	15	14	5	1	6	11	12	18	13	5	3	11	11
Galena limestone	16	7	18	6	1	1	.....	.....	.....	.....	2	4½	3	.....
Trenton limestone	58	60	43	49	71	70	65	79	54	68	67	74	63	58
St. Peter and Potsdam sandstone	1	.....	5	11	12	8	9	.....	3	7	9	8	3	3
Huronian quartzite	.....	1	.....	3	.....	1	4	.....	.....	3	1	.....	1	5
Archean crystalline rocks	9	8	13	11	7	7	3	9	23	5	6	10½	13	9
Chert and quartz	.....	1	.....	5	3	3	5	.....	.....	3	8	1	4	.....
Doubtful, mostly limestone	4	8	7	10	5	5	4	.....	2	3	2	2½	2	9
Proof	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Percentage of foreign material	9	8	13	11	7	7	3	9	23	5	6	10½	13	9

Number of analysis	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Town	Rock (T. 2 N., R. 12 E.)								La Prairie (T. 2 N., R. 13 E.)					
Section	1	3	14	15	22	26	25	25	3	5	6	19	21	31
Fraction	SE. ¼	NW. ¼	SE. ¼	E. ½	NE. ¼	NE. ¼	SW. ¼	SE. ¼	SW. ¼	NW. ¼	SE. ¼	SE. ¼	NW. ¼	SW. ¼
Niagara limestone	4	8	8	11	12	.....	13	20	10	8	16	5	17	20
Galena limestone	.....	.....	.....	1	.....	.....	.....	25	8	2	1	.....	12	16½
Trenton limestone	59	69	59	72	63	56	52	32	69	65	53	61	44	27½
St. Peter and Potsdam sandstone	9	4	8	3	7	6	1	4	1	2	.....	5	6	1
Huronian quartzite	2	2	2	2	1	2	3	.....	1	3	.....	2	.....	2
Archean crystalline rocks	9	5	12	9	11	14	18	13	12	13	18	13	10	24½
Chert and quartz	12	6	5	2	1	18	1	6	.....	1	4	9	4	1
Doubtful, mostly limestone	5	3	6	.....	5	4	12	.....	5	6	8	5	7	2
Proof	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Percentage of foreign material	9	5	12	9	11	14	18	13	12	13	18	13	10	24½

TABLE G.—*Outwash deposits bordering the Darien and Johnstown moraines*—Continued.

Number of analysis	29	30	31	32	33	34	35	36	37	38	39	40	41	42	
Town	Beloit (T. 1 N., R. 12 E.).						Turtle (T. 1 N., R. 13 E.).				Richmond (T. 3 N., R. 15 E.).	Darien (T. 2 N., R. 15 E.).	Bradford (T. 2 N., R. 14 E.).	Union (T. 4 N., R. 10 E.).	Averages (Galena and Trenton approximate).
Section	1	12	11	23	26	36	20	31	31	2	16	7	31	21	
Fraction	SE. ¼	NE. ¼	NW. ¼	SW. ¼	SW. ¼	SE. ¼	SW. ¼	NE. ¼	SE. ¼	NE. ¼	SW. ¼	SE. ¼	NE. ¼	W. ½	
Niagara limestone	22	21½	4	20	4	32	23½	24½	27	56	31½	32	33	.....	14.88
Galena limestone	18	16	7	14	39	14½	18	30	21	.....	36½	42	41½	49	9.918
Trenton limestone	41	39	45	44	28	33½	40	26½	29	29	8	.....	.....	.....	50.96
Lower Magnesian limestone (including Mendota limestone)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	29	.69
St. Peter and Potsdam sandstone	2	2½	5	2	4	3	3	3½	2	1	1½	1	4	15	4.388
Huronian quartzite	.....	½	1	.....	.....	.....	.....	½	3	½	1½	.....	1½	.....	1.17+
Archean crystalline rocks	13	17	29	20	22	13	9	13	13	13½	15½	19	18½	6	12.78
Chert and quartz	1	1	9	.....	2	½	1½	.....	2	.....	1	2	½	.....	2.93
Doubtful, mostly limestone	3	2½	.....	.....	1	3½	5	2	3	.....	½	4	½	1	3.99
Proof	100	100	100	100	100	100	100	100	100	100	100	100	100	100	101.016
Percentage of foreign material	13	17	29	20	22	13	9	13	13	13½	15½	19	12½	6	12.78

TABLE H.—*Darien terminal moraine of the Delavan lobe.*

Number of analysis	1	2	3	4	5	6	7	8	9	10
Town	Whitewater (T. 4 N., R. 15 E.).		Sugar Creek (T. 3 N., R. 16 E.).			Richmond (T. 3 N., R. 15 E.).				
Section	36	36	6	7	7	1	10	15	15	26
Fraction	SE. ¼	S. ½	N. ½	Mid.	W. ½	SW. ¼	SE. ¼	NW. ¼	E. ½	SW. ¼
Niagara limestone	68	59	59½	65½	64½	62	30	51	41	59
Galena limestone	7½	13	13½	13½	19	11	39	18	24	11
Trenton limestone	4	5	2½	2½	2½	4	7	2	12	6
St. Peter and Potsdam sandstone	.....	1	1	1½	.....	2	.....	2	.....	.....
Huronian quartzite	.....	.....	.....	.....	.....	.....	1	1	1	2
Archean crystalline rocks	13	17	18½	14	12½	14	14	22	10	20
Chert and quartz	.....	.....	1½	.....	.....	.....	.....	1	2	.....
Doubtful, mostly limestone	6	1	3½	3	1½	1	9	3	7	2
Proof	100	100	100	100	100	100	100	100	100	100
Percentage of foreign material	13	17	18½	14	12½	14	14	22	10	22

TABLE H.—*Darien terminal moraine of the Delavan lobe*—Continued.

Number of analysis	11	12	13	14	15	16	17	18	19
Town	Darien (T. 2 N., R. 15 E.)								Delavan (T. 2 N., R. 16 E.).
Section	2	10	13	15	22	24	26	36	30
Fraction	E. ½	SW. ¼	NW. ¼	S. ½	W. ½	SE. ¼	NW. ¼	SE. ¼	SW. ¼
Niagara limestone	51	57	38	46	48	47	51	55	56
Galena limestone	17	10	16	20	16	18	9	16	14
Trenton limestone	9	13	21	14	10	19	12	15	15
St. Peter and Potsdam sandstone		3	1	1	1		2		2
Huronian quartzite									
Archean crystalline rocks	15	13	18	15	18	14	17	12	9
Chert and quartz		1				1			1
Doubtful, mostly limestone	8	3	6	4	7	1	9	2	3
Proof	100	100	100	100	100	100	100	100	100
Percentage of foreign material	5	16	19	16	19	14	19	12	11

Number of analysis	20	21	22	23	24	25	26	27	28	29	
Town	Walworth (T. 1 N., R. 16 E.).		Bloomfield (T. 1 N., R. 18 E.) ..							Lyons (T. 2 N., R. 18 E.).	Averages (Galena and Trenton, approximate).
Section	16	15	22	25	20	8	6	5	3	24	
Fraction	NW. ¼	NE. ¼	N. ½	Mid.	W. ½	SE. ¼	SE. ¼	W. ½	W. ½	SW. ¼	
Niagara limestone	56	57	62	71	86½	80½	79½	80	90	82½	60.69
Galena limestone	19		26								12.24
Trenton limestone											6.38
St. Peter and Potsdam sandstone	2	3			½		½	½		½	0.86
Huronian quartzite	1					½	½	½	½	½	0.278
Archean crystalline rocks	19	15	12	12	13	19	19½	19½	9½	16	14.82
Chert and quartz											0.27+
Doubtful, mostly limestone	3	25		17					½	½	4.32
Proof	100	100	100	100	100	100	100	100	100	100	99.818
Percentage of foreign material	22	18	12	12	13½	19½	20½	20	9½	16½	15.74

TABLE I.—*Elkhorn terminal moraine of the Delavan lobe.*

Number of analysis	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Town	Palmyra (T. 5 N., R. 16 E.).		Troy (T. 4 N., R. 17 E.).	Lagrange (T. 4 N., R. 16 E.).				Lafayette (T. 3 N., R. 17 E.).	Sugar Creek (T. 3 N., R. 16 E.).					
Section	35	36	6	14	24	26	29	7	10	14	16	21	34	31
Fraction	N. ½	SW. ¼	S. ½	SE. ¼	S. ½	NW. ¼	E. ½	S. ½	NE. ¼	S. ½	W. ½	S. ½	N. ½	S. ½
Niagara limestone	56	65	65½	56½	63	69	53½	71	58½	72	70½	56	58	51
Galena limestone	21	15	11	.....	7	13	7	5	14½	7	13	6	11	11
Trenton limestone	.....	.....	4	12	.....	.....	17½	12	½	.....	.....	15	11	17
Lower Magnesian limestone (including Mendota limestone)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
St. Peter and Potsdam sandstone	.....	.....	2	2	4	.....	3	1	1	1	1	.....	.....	3
Huronian quartzite	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....
Archean crystalline rocks	23	17	14½	24½	24	11	18½	10	22½	13	12	19	18	14
Chert and quartz	.....	.....	½	.....	.....	.....	½	.....	.....	.....	.....	2	.....	.....
Doubtful, mostly limestone	.....	3	3½	3	2	7	.....	1	2	7	3½	2	1	4
Proof	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Percentage of foreign material	23	17	14½	24½	24	11	18½	10	22½	13	12	19	18	17

Number of analysis	15	16	17	18	19	20	21	22	23	24	25	26	27	
Town	Delavan (T. 2 N., R. 16 E.)							Geneva (T. 2 N., R. 17 E.).		Lyons (T. 2 N., R. 18 E.).		Burlington (T. 2 N., T. 3 N., R. 19 E.).		Averages (Galena and Trenton approximate).
Section	7	8	8	9	21	3	14	29	24	17	10	6	31	
Fraction	E. ½	NW. ¼	SW. ¼	NW. ¼	S. ½	S. ½	SE. ¼	NW. ¼	N. ½	NW. ¼	SE. ¼	NW. ¼	NW. ¼	
Niagara limestone	59	45	53	47	75	54	51	74	77	59	80⅛	82⅜	86⅛	64.05
Galena limestone	7	12	11	11	2	11	15	.....	11	.....	.....	.....	.....	7.64
Trenton limestone	15	11	12	17	8	18	9	.....	.....	1	.....	.....	.....	7.49
Lower Magnesian limestone (including Mendota limestone)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
St. Peter and Potsdam sandstone	2	2	1	4	1	.....	2	.....	.....	.....	⅜	⅛	.....	1.20
Huronian quartzite	.....	.....	.....	.....	.....	.....	.....	.....	1	5	⅜	⅛	.....	.28
Archean crystalline rocks	16	26	18	17	12	17	20	12	7	15	17⅛	16⅛	13⅛	16.62
Chert and quartz	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	⅛	⅜	.....	.13
Doubtful, mostly limestone	1	4	5	4	2	.....	3	14	4	20	⅛	.....	.....	3.65
Proof	100	100	100	100	100	100	100	100	100	100	100	100	100	101.06
Percentage of foreign material	18	28	19	21	13	17	22	12	8	20	18⅜	17⅛	13⅛	17.46

TABLE J.—*Valparaiso terminal moraine system.*

Number of analysis	1	2	3	4	5	6	7	8	9	10	11
Town	Genesee (T. 6 N., R. 18 E.).	New Berlin (T. 6 N., R. 20 E.).			Muskego (T. 5 N., R. 20 E.).			Waterford (T. 4 N., R. 19 E.).			
Section	35	29	31	32	5	8	9	27	34	35	36
Fraction		SE. ¼	SE. ¼	SW. ¼	Mid.	NE. ¼	SE. ¼	SW. ¼	NE. ¼	NW. ¼	NE. ¼
Niagara limestone	86½	82.4	89.5	86	86.1	89.4	92.3	89.5	82.7	91	86.2
Galena limestone											
Trenton limestone											
Lower Magnesian limestone (including Mendota limestone)											
St. Peter and Potsdam sandstone	½	.5	.8	½	.2	.1	.2		.6		.1
Huronian quartzite					.1		.1		1.4		
Archean crystalline rocks	13	17.1	9.7	13½	11.6	10.5	6.9	10.5	15.3	9	13.7
Chert and quartz											
Doubtful, mostly limestone							.2				
Proof	100	100	100	100	100	100	100	100	100	100	100
Percentage of foreign material	13½	17.6	10.5	14	11.9	10.6	7.2	10.5	17.3	9	13.8

Number of analysis	12	13	14	15	16	17	18	19	20	
Town	Rochester (T. 12 N., R. 13 E.).		Burlington (T. 3 N., R. 19 E.).		T. 2 N., R.		Brighton (T. 2 N., R. 20 E.).	Salem (T. 1 N., R. 20 E.).	Randall (T. 1 N., R. 19 E.).	Averages.
Section	13	18	29	5	4	15	19	20	20	
Fraction	NW. ¼	NW. ¼	SW. ¼	NW. ¼	SW. ¼	SE. ¼	N. ½	SW. ¼	SW. ¼	
Niagara limestone	87½	84½	83	84	83½	91	88½	83½	84½	86.724
Galena limestone										
Trenton limestone										
Lower Magnesian limestone (including Mendota limestone)										
St. Peter and Potsdam sandstone		½		½	½	½	¼	1	½	.365
Huronian quartzite		½	½	½		½	1	1/16		.184
Archean crystalline rocks	12½	14½	16½	14½	15½	8	10½	14½	15	12.71
Chert and quartz				½		½		1/16		.008
Doubtful, mostly limestone				½						.005
Proof	100	100	100	100	100	100	100	100	100	99.991
Percentage of foreign material	12½	15.5	17	15½	16½	8½	11½	15.9	15½	13.259

TABLE K.—*Lake-border morainic system.*

Number of analysis	1	2	3	4	5	6	
Town	Lake (T. 6 N., R. 21 E.).	Greenfield (T. 6 N., R. 21 E.).	New Berlin (T. 6 N., R. 20 E.).	Muskego (T. 5 N., R. 20 E.).	Franklin (T. 5 N., R. 21 E.).		Averages.
Section	7	32	36	12	7	35	
Fraction	NW. ¼	SW. ¼	SW. ¼	SE. ¼	NE. ¼	N. ½	
Hamilton limestone and shale	11½	⅛	.....	⅛	.....	9½	3.62
Salina formation	18⅛	1½	.....	2½	1/16	9½	5.41
Niagara limestone	49½	81⅛	90½	81½	92½	64	76.63
Galena limestone	.....	.....	.....	.....	.....	.....	.....
Trenton limestone	.....	.....	.....	.....	.....	.....	.....
Lower Magnesian limestone	.....	.....	.....	.....	.....	.....	.....
St. Peter and Potsdam sandstone	⅜	⅛	½	½	½	1½	.81
Huronian quartzite	⅛	.....	.....	⅛	.....	.....	.116
Archean crystalline rocks	16⅜	15	9	14⅛	6½	15½	12.76
Chert and quartz	.....	.....	.....	.....	.....	.....	.....
Doubtful, mostly limestone	3⅛	.....	.....	.....	.....	.....	.63
Proof	100	100	100	100	100	100	99.99
Percentage of foreign material	17⅜	15⅛	9½	15½	7	17	13.70

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GEOLOGY OF THE PERRY BASIN

IN

SOUTHEASTERN MAINE

BY

GEORGE OTIS SMITH and DAVID WHITE

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., May 27, 1904.

SIR: I have the honor to transmit the manuscript of a report on the geology of the Perry basin, in southeastern Maine, by George Otis Smith and David White, and to recommend its publication as a professional paper.

This report embodies the results of an investigation of alleged coal deposits, made in cooperation with the Maine State Survey Commission. While from an economical standpoint the results are entirely negative, they are none the less important and are of great scientific interest.

Very respectfully,

C. W. HAYES,
Geologist in Charge of Geology.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

THE GEOLOGY OF THE PERRY BASIN, IN SOUTHEASTERN MAINE.

By GEORGE OTIS SMITH and DAVID WHITE.

INTRODUCTION.

EXPLANATION OF THE INVESTIGATION.

The geologic examination of the Perry district, in southeastern Maine, was undertaken at the request of the Survey Commission of the State of Maine. During the 1902–3 session of the Maine legislature an effort was made by petitioners resident in Washington County to obtain from the State an appropriation of $10,000 for coal exploration. The resolve proposed contained a proviso necessitating an additional contribution of $5,000 by individuals or corporations interested. The $15,000 thus procured was to be expended in drilling for coal at the most promising localities. The resolve failed to pass, but the Maine Survey Commission decided that the same results could be accomplished by the expenditure of a small portion of the general appropriation for geologic work in cooperation with the United States Geological Survey.

The authors were detailed by the Director of the United States Geological Survey to make the investigation of the Perry region, under the direction of the Maine commissioners, for the purpose of determining the possibilities of the occurrence of coal in commercial quantities. As will be shown later, the region is especially favorable to geologic work, and a ten-day reconnaissance yielded data upon which definite conclusions can be based. These conclusions are presented in this paper, together with observations incidentally made that have a bearing upon the general geologic problems of the region. It is believed that the results thus obtained in answer to the inquiry as to the occurrence of coal are even more definite than those which would have been reached by the expenditure of the proposed appropriation in extensive drilling operations.

In the preparation of the report the observations and deductions of both authors have been used, but Chapters I and III have been written by Mr. White and Chapters II and IV, with the added descriptions of other localities visited, by

Mr. Smith. A preliminary statement of the results was submitted to the Maine Commission August 5, 1903, and published by it in the daily press of the State on the following day.

STATEMENT OF CONCLUSIONS.

In this paper it will be shown, regarding the geologic relations, that—

1. The Perry formation, consisting chiefly of brownish conglomerates and interbedded lavas, lies in irregular areas in marked unconformity on earlier formations, the youngest of which is probably of a date not later than the oldest Devonian.

2. The formation is estuarine and was rapidly deposited, the materials being derived, without long transport, from rocks immediately adjacent to the area of deposition.

3. The lower beds of the formation are more coarsely and massively conglomeratic toward the north, and the higher beds are accompanied by a larger proportion of intrusive rocks.

4. Since the deposition of the Perry beds there has been no very marked folding and but slight alteration of the sediments, though minor faulting and some cutting by intrusives have occurred.

5. The lavas of the Perry formation are basic as compared with those of Silurian age, which are of a rhyolitic type.

6. The age of the formation is distinctly Devonian, and probably Chemung.

Regarding the occurrence of coal it is found that—

1. The strata of the formation, which are exposed in exceptional completeness, bear no evidence of the presence either of any seam of coal, of whatever thickness, or of any of the usual and more or less characteristic accompaniments of coal seams, such as old soils, Stigmaria clays, leached plant shales, etc., there being no traces of even carbonaceous or black-shale beds or partings.

2. The fossils show that the rocks are of upper Devonian age; i. e., that they were laid down in a period earlier than the deposition of any commercially workable coals yet discovered on any continent. There is therefore no basis whatever for the hope of finding usable coal in any of the concealed parts of the Perry formation.

3. There are no rocks of coal-bearing age under the Perry formation. The youngest of the remaining Paleozoic rocks of the region, beneath and surrounding the Perry formation, are far more ancient than the rocks of the Perry formation. The last drill prospect is shown to have passed through the Perry formation and into the lavas of Silurian age.

4. The reports of coals do not, when investigated, conflict in the least with the foregoing conclusions.

CHAPTER I.

REVIEW OF LITERATURE.

By DAVID WHITE.

The vicinity of Perry has perhaps attracted more attention on the part of geologists than any other portion of eastern Maine. The presence in the Perry basin of the youngest Paleozoic rocks yet definitely determined in the State, the relative proximity of this basin to the coal fields of Nova Scotia and New Brunswick, and the lithologic resemblance between the rocks of the basin and those associated with the coal measures lying farther northeastward are conditions which, since the earliest geologic explorations in the State, have combined to excite interest in this region as one favorably situated for the occurrence of coal. The researches were therefore carried on chiefly with an economic motive.

Geographically and structurally the Perry basin is most closely bound to southern New Brunswick. Accordingly we find its geologic features compared with those of that Province, its formations having been included by the Canadian geologists in their discussions of the upper Paleozoic axis of the Bay of Fundy, with which the Perry basin is continuous.

As early as 1836[a] Dr. Charles T. Jackson, in the service of both Maine and Massachusetts, published numerous details of the geology of eastern Washington County, including descriptions of the eruptives and red sandstones and conglomerates about Perry. The sandstones, described as extending along the St. Croix River from Indiantown to Liberty Point, in Robbinston, were identified as belonging to the coal formation of New Brunswick and Nova Scotia, though, as was explained, until the sequence should be traced across from the Grand Lake (New Brunswick) coal field it remained impossible to fix their exact position with reference to any coal beds assumed to be near. The term "New Red sandstone" was applied[b] to some of these beds along the St. Croix River, and they were correlated with the older Mesozoic of Connecticut and the gypsiferous and coal-bearing series of

[a] First Rept. Geol. Public Lands, State of Maine; Mass. S. Doc. No. 89, March, 1837, pp. 11, 12, 18. First Rept. Geol. Maine, 1837, pp. 17, 18, 97.

[b] First Rept. Geol. Maine, 1837, p. 97.

Nova Scotia. On the basis of this supposed identity of formation Professor Jackson recommended the exploration, by boring or otherwise, for coal, which, if present, he thought should be found between Pembroke and the St. Croix. He says:

"From the observations which we have been able to make it will appear that the sandstone here described is a continuation of that which exists in New Brunswick and in which the bituminous coal of the Grand Lake is probably contained. It will, however, be impossible for me to speak positively on this subject until I have visited that district, for no survey of the region has ever been made. It is, however, an undoubted fact that the sandstone in question is identical with the red sandstone of Nova Scotia which contains gypsum, salt springs, and coal. In a subsequent excursion around Lubec Bay we found a salt spring, which issues from the soil near the junction of this sandstone with the argillaceous limestone rock, above the Lubec lead mines. The New Red sandstone rests directly on the transition limestone at Pembroke. It occurs also at Red Head, Nutters Point, where it is of an exceedingly fine texture and will serve perfectly for the manufacture of hones and fine grindstones for delicate tools.

"If coal really occurs in this sandstone, it should be found between the village of Pembroke and the St. Croix River. In the present state of our knowledge of the country it is impossible to say more respecting the occurrence of coal in this section. It not unfrequently happens that some members of the coal series are wanting, which may possibly be the case here. It is, however, worthy of exploration, and by boring through this rock in a few places the question may be settled at little expense to those who may enter on the task.

"Should no such operations be carried on before the next year, I hope to be allowed to extend my researches to the known coal regions of New Brunswick, on the Grand Lake, when more light may be obtained on this important subject. The numerous irregularities to which our coal measures are subject render it difficult, if not impossible, to trace them without the aid of immediate comparisons of one section with another. No geological observations would imply that the red sandstone in question should not contain coal; for if it should be found equivalent to the New Red sandstone formation of Europe, it will belong to the upper coal series. The occurrence of a salt spring at its junction with the limestone appears to favor this supposition."[a]

The same views are implied in Doctor Jackson's second report[b] as State geologist, made in 1838. Nevertheless, as will be seen later, the correlations on which he based his hope of developing a coal field in this basin, and which were accepted by Gesner, the geologist of New Brunswick, were entirely false and misleading.

For a score of years following the close of Doctor Jackson's survey, the literature, so far as it concerns the Perry formation, relates chiefly to the classification and age of the coal- or copper-bearing red sandstones of North America. This discussion was participated in by the most eminent American geologists of the period.

[a] First Rept. Geol. Maine, 1837, pp. 17, 18.

[b] Second Ann. Rept. Geol. Public Lands of Maine and Massachusetts, Boston, 1838, p. viii.

In 1851 Jackson, though insisting that the red sandstones overlying the Silurian in Maine were of the same age as those in the Connecticut Valley or in New Jersey, suggested[a] that all of the deposits in question might belong in the Silurian system. This proposition was promptly combatted by Agassiz, who urged[b] that the vertebrate remains of the New Jersey red beds should not be regarded as older than the Trias.

In 1859 the current of opinion as to the age of these rocks was turned from a later to an earlier age, apparently by a fossil plant. In that year Prof. W. B. Rogers laid before the Boston Society of Natural History[c] "specimens of the supposed coal-bearing rocks of Maine, in which was an impression closely resembling *Cycloteris hibernica*, so common in Great Britain." Professor Newberry concurred as to the affinities of this species, and Professor Rogers was accordingly of the opinion that the Perry beds were to be correlated with the "Kiltorcan" (Devonian or "Ursa," but regarded by him as lower Carboniferous) of Ireland, the "Albert shales" of New Brunswick, and the Pocono coal-bearing series of the Appalachian region, all being referable to the lower Carboniferous. Later he was disposed to regard the Perry beds as upper Devonian, or transitional to the Carboniferous. About the same time Jackson stated[d] that, although at first disposed to consider the Perry beds as "New Red" or Triassic, he had since come to regard them as Devonian, since he had traced the red sandstones from Perry to Trescott and Machias, where they rest on beds of Silurian if not Devonian age, but that "fossils recently discovered seemed to indicate that his first conjecture, that these rocks are Triassic, was well founded." This was followed by a reiteration on the part of Agassiz[e] that the red sandstone of southern New Brunswick was Triassic, additional proof being cited in the form of a *Calamites* supposed by him to be close to the Triassic *Equisetum columnare*.

In the meantime shafting and boring had been carried on in the Perry basin in the search for coal, and the careful scrutiny of the rocks had led to the discovery of additional fossil plants. Accordingly, when, in 1861, Prof. C. H. Hitchcock entered upon his duties as State geologist of Maine, he called to his aid, in the determination of the vexed Perry question, the services of Prof. J. W. (later Sir William) Dawson, who had already begun the publication of his valuable series of papers on the Paleozoic floras of northeastern America. Hitchcock's report[f] contains the most accurate and detailed description of the geologic features of the basin that has yet appeared, though, as in previous reports, the Perry sandstone was not in all areas

[a] Proc. Boston Soc. Nat. Hist., vol. 3, p. 335.
[b] Loc. cit., p. 337.
[c] Proceedings, vol. 5, pp. 86, 170, 398.
[d] Loc. cit., pp. 396–398.
[e] Loc. cit., pp. 357, 398.
[f] Sixth Ann. Rept. Sec. Maine Bd. Agric., Augusta, 1861 (1862), pp. 247–257, 208.

distinguished from the red shales of the Silurian. The most important part of this report, however, so far as it relates to the prospect of finding coal in this basin, is that giving the results of Dawson's study of the fossils and enumerating or describing seven species of fossil plants found at Perry. In view of the character and distribution of these species Dawson unqualifiedly asserted his conclusion that the beds were of Devonian age, thus confirming his previous views, which were almost simultaneously published,[a] but which had been based on a smaller amount of material.

The conclusions, accompanied by paleontological evidence, first set forth by Sir William Dawson, met prompt and general acceptance at the time by Hitchcock[b] and others, though more precise correlations were not given until later, when, as additional material was discovered and the distribution of the species was better known, his comparison of the Perry flora became more exact. Thus, in Dawson's next papers[c] on the subject, in the following year, he refers the Perry beds (estimated at 1,300 feet) to the upper Devonian and correlates them with the upper member of the "St. John Series" and the upper Devonian of Gaspé. In the next year Dawson[d] had recognized 16 forms in the Perry flora, which he correlated as before, while cautioning explorers of this region "that these rocks strikingly resemble in their mineral characters the lower Carboniferous red sandstones and conglomerates of some parts of Nova Scotia and New Brunswick, and also probably Mesozoic 'New Red sandstones' of these Provinces."

These words of Dawson reflect his embarrassment in correlating the relatively unaltered Perry beds with the lithologically strikingly dissimilar and somewhat metamorphic St. John beds, or "fern ledges," lying farther northeastward in the same basin at Lepreau and St. John, along the Bay of Fundy. This difficulty seems to disappear when he concludes[e] that the beds at Perry "may belong to a Devonian horizon somewhat higher than that of the St. John beds, and that this may possibly serve to account for their comparatively unaltered condition." He reiterates, however, that "the flora of the Perry beds is precisely equivalent to that of the upper Devonian of Pennsylvania and New York, and quite distinct

[a] On the pre-Carboniferous flora of New Brunswick, Maine, and eastern Canada: Canadian Naturalist, vol. 6, June, 1861, pp. 172–175. The collections studied by Dawson were those of the Portland Society of Natural History and a collection made by Mr. Richardson, of the Geological Survey of Canada.

[b] Proc. Portland Soc. Nat. Hist., vol. 1, pt. 1, 1862, pp. 76–78. In this paper Professor Hitchcock points out the fact that the paleontological equivalents of the Perry beds underlie the lower Carboniferous of the Bay of Fundy region, and he calls attention to the consequent conclusion that the Carboniferous does not occur in Maine, and that "we need no longer expect to find beds of coal in Perry."

[c] On the flora of the Devonian period in northeastern America: Quart. Jour. Geol. Soc. London, vol. 18, November, 1862, pp. 296–330, pls. xii–xvii; reprinted in part, Am. Jour. Sci., 2d ser., vol. 35, 1863, pp. 311–319. Descriptions of new fossils: Second Ann. Rept. Nat. Hist. and Geol. Maine, 1863, pp. 402, 404; reprinted in Proc. Portland Soc. Nat. Hist., vol. 1, pt. 2, 1863, pp. 99, 100, pl. ii.

[d] Further observations on the Devonian plants of Maine, Gaspé, and New York: Quart. Jour. Geol. Soc. London, vol. 19, November, 1863, pp. 458–469, pls. xvii–xix. Acadian geology, 1868, p. 513.

[e] The fossil plants of the Devonian and upper Silurian formations of Canada: Geol. Survey Canada, 1871, pp. 6, 11, 68, 71, 85.

from that of the lower Carboniferous," and in his table[a] the sandstones about Perry are put opposite the Chemung of New York and the upper Devonian of Gaspé.

The difficulties met in reconciling a Devonian correlation of the Perry beds with the great section near St. John adopted by the New Brunswick geologists as typical of the Devonian for the southern part of their province seems to have increased as the stratigraphic studies of Prof. L. W. Bailey, Dr. G. F. Matthew, and Prof. C. F. Hartt were carried along the Bay of Fundy to the shores of Passamaquoddy Bay. In the same year in which Dawson's report, just mentioned, was printed we find Bailey and Matthew[b] placing the "Perry sandstone group" "at or near the base of the lower Carboniferous," although, since at Perry and St. Andrews they contain Devonian forms of vegetation, it was thought that they might be of earlier date than the lower Carboniferous of the Kennebecasis Valley. This reference we find reaffirmed in 1880 by Bailey, Matthew, and Ells, who, in discussing the outlying deposits on the shores of the Passamaquoddy Bay, explain that[c] "these are interesting as containing in their lower portions fossils of a Devonian type, while the beds themselves are uncomformably superimposed upon the true Devonian, and otherwise possess the characters of the lower Carboniferous rocks."

The second part of Dawson's Fossil Plants of the Erian and Upper Silurian Formations of Canada appeared in 1882,[d] and among the more exact correlations contained therein we again find the Perry beds placed at the top of the Devonian, on a level with the "*Pterichthys* beds" of Scaumenac, New Brunswick. This conclusion was unqualifiedly stated in all of Sir William's later references to the Perry formation.[e] Nevertheless, the stratigraphers of the Canadian Survey seem genrally to have decided that the stratigraphic tracing of the beds admitted no doubt as to the identity of the Perry with the lower Carboniferous of the Bay of Fundy basin, to which it is very closely similar lithologically; and we find the Perry formation mapped as lower Carboniferous by the Geological Survey of Canada on the detailed geologic sheet embracing this portion of the international boundary.[f]

An important paper relating to the Perry formation was published by Prof. N. S. Shaler in 1886, under the title "Preliminary Report on the Geology of the Cobscook Bay District, Maine."[g] This paper is devoted chiefly to the lithology, stratigraphy, and fossils of the rocks, which he classifies in four groups, three

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[a] Foss. Pl. Dev. Upp. Sil. Form., Canada, p. 11.
[b] Geol. Survey Canada, Rept. for 1872, p. 200.
[c] Geol. Survey Canada, Rept. for 1880, pp. 12D, 15D.
[d] Geol. Survey Canada, for 1882, p. 113.
[e] See Geological History of Plants, 1888, p. 107; also, Geology of New Brunswick, Nova Scotia, and Eastern Canada, 1891, Suppl., p. 73.
[f] Geol. Survey Canada, Province of New Brunswick, No. 1 S. W., 1880.
[g] Am. Jour. Sci., 3d ser., vol. 32, pp. 35–60.

of these being below the Perry group, the highest of the latter, the Cobscook, including dark sandstones and shales ("Moose Island Black shale"), probably approximately of the date of the "Ohio" ["Hamilton"] shale. These groups are—

1. A basal series, of unknown thickness, consisting of gneissoid, syenitic, and granitic rocks and some mica-schists, probably of Laurentian age.

2. The "Campobello group," comprising dark greenish, grayish, siliceous, and argillaceous rocks with very little lime and no fossils, over 4,000 feet thick, to be compared with the Cambrian.

3. The "Cobscook series," not less than 4,000 feet of more or less altered sandstones, shales, limestones, ash beds, and intrusives, carrying at points Clinton, Niagara, lower Helderberg, and middle Devonian (?) fossils.

4. The "Perry series," over 2,000 feet of coarse, red conglomerates and sandstones unconformably deposited, of upper Devonian or lower Carboniferous age.

The structure of the basin and the erosion intervals between the groups are discussed at some length, though the red Silurian does not seem at all points to have been distinguished from the Perry, which, with its coarse, red sandstones, conglomerates, and reddish shales, estimated as certainly over 2,000 feet in thickness, he regards as a shore or estuarine deposit distinctly unconformable on the older groups.

Professor Shaler adds:

"If the lower part of the section at Perry should turn out to be upper Devonian or sub-Carboniferous, as seems not improbable, then the evidence will be to the effect that a period of erosion occurred in the interval between the close of the middle Devonian and the formation of the Perry beds. This is especially interesting, as it would seem to show that this portion of the continent was above the sea during a part of the Devonian or of the sub-Carboniferous period."[a]

In the Cobscook group, which is next below the Perry group, Shaler recognizes four faunas: A lower Helderberg, at Orange Bay; a fauna closely related to the Clinton or Niagara, at Dents Point; a Niagara fauna, near Demysville, and the fauna of the "Moose Island Black shales," for which he argues a middle Devonian age. For the latter correlation the age evidence, which is in part merely circumstantial and lithologic, does not appear sufficient. The paleontological evidence on which these age determinations were based will be briefly considered in a later part of this paper (p. 22). In a footnote[b] the author remarks:

"It may be incidentally suggested that the conglomerates and sandstones of the Perry series should be compared with the deposits of the 'Catskill period' of the Hudson district."

[a] Loc. cit., p. 50.

[b] Loc. cit., p. 51.

Finally, it is interesting to note a conclusion regarding the Perry group more recently presented by Prof. L. W. Bailey, in a paper "On some Relations between the Geology of eastern Maine and New Brunswick," wherein the following statement is made:[a]

"In its fossil flora, so well described by Sir William Dawson, its aspect is undoubtedly Devonian, but to the other rocks of that system, as seen only a few miles to the eastward, along the New Brunswick coast, it bears no resemblance whatever, while, both in the nature of the beds and in their relations to the subjacent formations, it does bear much resemblance to the rocks of the lower Carboniferous system which spread so widely over other portions of the province. For this reason it was, in the survey reports and maps, represented as a part of the last-named system. On the other hand, however, it differs from the latter in the total absence of the marine limestones and gypsiferous beds usually found in connection therewith, and in this respect approaches more nearly a group of coarse sediments skirting the shores of the Bay des Chaleurs, which have been there shown to be unconformably overlapped by the lower Carboniferous or Bonaventure rocks. It is probable that in both instances these coarse red beds, though true Devonian, are to be regarded as representing the most recent portion of that system, and like the Catskill group of New York, which they nearly resemble, constitute a transitional series between the two."

It is thus seen that the conclusions of Professor Bailey and the suggestions of Professor Shaler are in substantial agreement with the correlation first proposed by Sir William Dawson, notwithstanding the consequent difficulties involved in the correlation of the supposed Devonian and lower Carboniferous rocks along the Bay of Fundy between the St. Croix River and St. John.

[a] Trans. Royal Soc. Canada, vol. 7, sec. 4, 1889, p. 60.

CHAPTER II.

DESCRIPTIVE GEOLOGY.

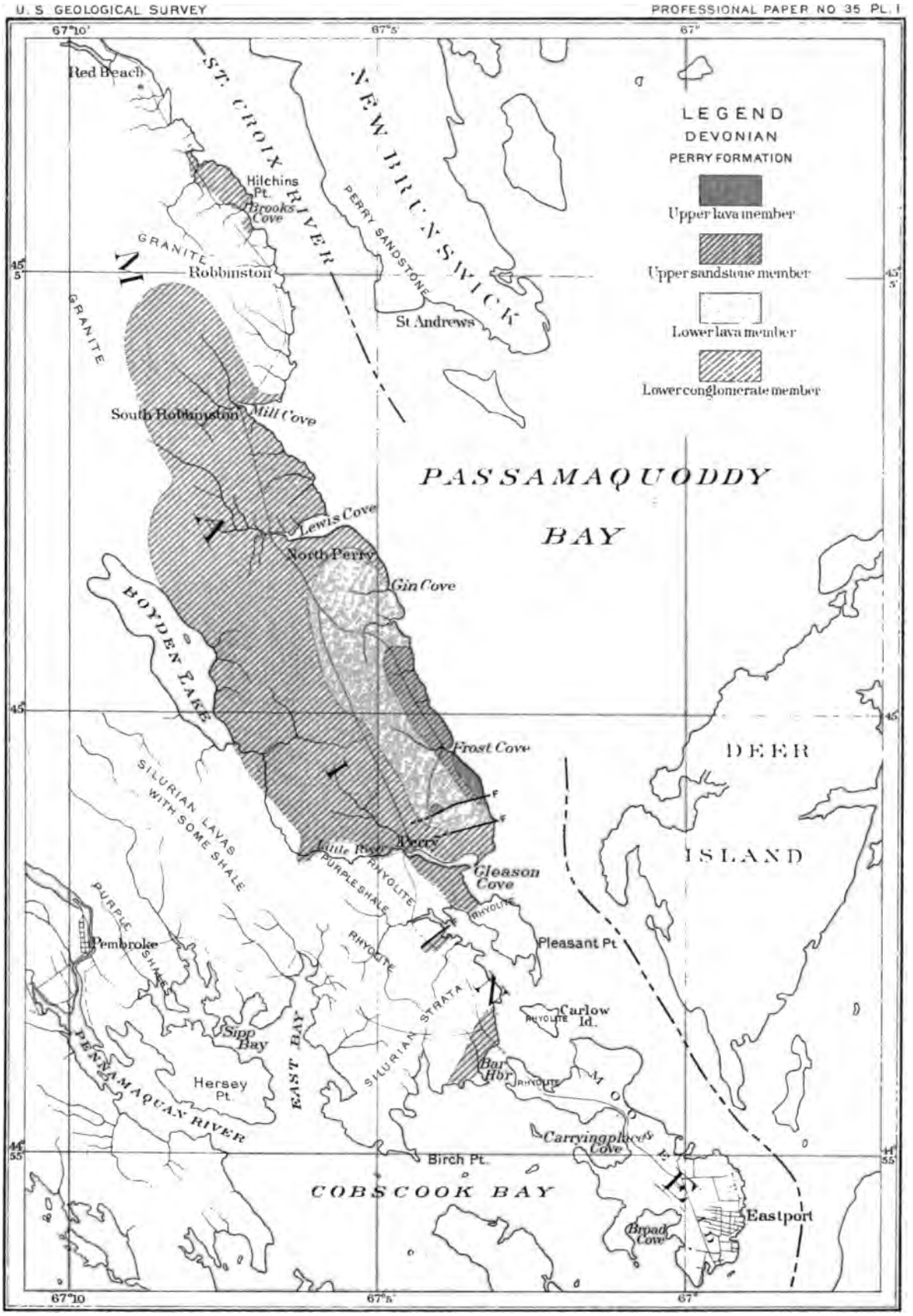
By GEORGE OTIS SMITH.

CONDITIONS OF GEOLOGIC WORK.

The natural conditions in this coast region may be said to favor geologic mapping. It is true that in the interior portion of the area outcrops may not be everywhere as numerous as the geologist might desire, although in our rapid traverse of the principal roads the rock exposures were found to be sufficiently abundant to serve the purpose of the reconnaissance. Yet the coast line is here characterized by a very extensive development of deep indentations and projecting peninsulas, and along the most of this complicated shore line the very strong tides of Passamaquoddy and Cobscook bays have been effective in sea erosion. Thus sea cliffs have been carved that expose large faces of rock, and in these and in the outlying stacks, ledges, and reefs the rock strata can be easily studied. At the base of the cliffs the rock is in places swept clean by the tide, so that it is often possible to study contacts or dikes in both horizontal and vertical sections.

These favorable conditions prevail especially along the western shore of St. Croix River, where the Perry formation is exposed. Thus the conclusions reached concerning the stratigraphy and structure of this formation are for the most part definite. Rarely is the geology of an area so easily read and the problem to be investigated so readily solved.

In this reconnaissance of the Perry district the greater part of the time was devoted to the Perry formation itself. The shore section was carefully studied from Red Beach as far as the highway bridge at the northern end of Moose Island. The western and northern limits of the area of Perry rocks were determined approximately by road traverses, and at the same time the rocks forming the floor upon which the Perry sediments had been deposited were observed, the reconnaissance extending as far west as Pembroke. For the purpose of obtaining a broader knowledge



GEOLOGIC MAP OF THE PERRY BASIN, SOUTHEASTERN MAINE

BY

GEORGE OTIS SMITH AND DAVID WHITE

Scale

0 1 2 3 miles

1904

JULIUS BIEN & CO. LITH. N.Y

of the Perry formation the adjacent parts of New Brunswick were also visited and the sections exposed there were studied. In short, the work was planned so as to obtain as much information as possible regarding the stratigraphy, structure, and age of the Perry formation. The older rocks were studied chiefly in their relations to this formation, although some other observations will be recorded in this paper, because of their importance in the interpretation of the geology in other parts of the State.

OLDER FORMATIONS.

The rocks older than the Perry formation are of three classes—the granitic rocks, the Silurian sedimentary strata, and the associated volcanics. These will be described briefly, since some knowledge of them has proved to be essential to the solution of the question under discussion. Especially is this true of the Silurian rocks lying directly beneath the Perry conglomerate, from the fact that coal prospectors have sometimes failed to recognize these as older than the formation in which they hoped to find coal.

GRANITE.

Granitic rocks extend along the St. Croix River from near Calais to Robbinston. At Devils Head there are prominent exposures of granitic rocks. On the northwest slope of this promontory several types of igneous rock occur. In the same quarry opening light-pink granite and a dark-green rock are exposed in parallel sheets. The former is granite of the normal type, containing only a small proportion of biotite, while the latter has the composition of granite, but contains larger amounts and greater variety of the darker constituents, pyroxene being probably present with the hornblende and biotite. Some masses of coarse diabase also occur at this locality and the relations indicate a complex intermixture of several distinct intrusions of plutonic rock, which may, however, represent a common magma.

Farther south, at Red Beach, the granite is uniform in both color and texture. This granite is quarried extensively and the product of the Red Beach quarries has an excellent reputation in the market. Its attractive red color, fine grain, and even texture are qualities that fit it for the best work, since it takes a high polish.

In the town of Robbinston the red granite is slightly different in character. It is of even finer grain, and quartz, orthoclase, and plagioclase constitute almost the whole of the rock. In the specimen collected here a slight amount of chlorite represents the ferromagnesian constituent, which was probably biotite. In texture it approaches graphic granite, the quartz not being a younger constit-

uent than the orthoclase, but in places showing the peculiar intergrowth with that mineral. Both the feldspars are deeply colored with iron oxide, the plagioclase being slightly lighter in tint. It is this coloring matter in the feldspars that gives the bright-red color to the granite of Red Beach and Robbinston, and, as will be shown later, to the Perry sandstones as well.

Age of granite.—The exact age of the granitic rocks is an interesting point for determination. This question has no special importance in this investigation, but its bearing upon the geology of this portion of the State is direct enough to warrant brief mention here.

The granitic rocks that directly underlie the Perry formation in the town of Robbinston were regarded by Shaler as "of presumably Laurentian age." Bailey and Matthew, however, as early as 1872, recognized much of the granite as "intrusive," although there would be difficulty in separating this from the Laurentian granite. The "red syenitic rock" on the east side of the St. Croix River is described as appearing to graduate into feldspathic beds, which are in turn succeeded by "amygdaloidal traps" and sandstones containing *Modiolopsis* and *Lingula*.[a] In a later report[b] by these geologists this "Nerepis granite" is assigned to late Devonian time.

The observations made in connection with the present investigation confirm in part the conclusions of Bailey and Matthew. The red granite at Robbinston is the western continuation of their "Nerepis granite" and in its general appearance also resembles somewhat the "felsites" interbedded with the Silurian sandstone. The red granite and the red spherulitic lava, already described, are similar in composition and in the manner in which the orthoclase is colored. The latter feature probably has little value except as it explains the general resemblance of the two rocks as they are seen in weathered outcrops. In view, however, of their similarity in mineralogic and inferred chemical composition, it seems probable that these rocks are plutonic and effusive representatives of the same magma and are to be correlated in age in a general way. The granitic intrusions thus may not have ceased until later Silurian time, the rhyolitic lava on the north end of Moose Island being a flow from the same magma from which the granite now exposed at Red Beach had been derived. Neither granite nor rhyolite contributed pebbles to the Silurian sediments, but their detritus constitutes the bulk of the Perry conglomerate, as will be seen from the descriptions in the following chapter.

The evidence thus appears to support the conclusion that the red granite of Robbinston as well as the red rhyolitic rocks of Perry and the north shore of Moose Island are of late Silurian or of early Devonian age.

[a] Geol. Survey Canada, Rept., 1872, p. 188. [b] Geol. Survey Canada, Rept., 1880, p. 22D.

SILURIAN STRATA.

A small area of slates was observed a short distance south of Red Beach. This occurrence, however, is not so favorable for detailed observation as are the larger areas south of Perry, and therefore the extent of the rocks here was simply mapped and their age provisionally considered as Silurian.

The Silurian rocks in the southern part of Perry and in the adjoining town of Pembroke, as well as on the neighboring islands, have been studied by the New Brunswick geologists and by Professor Shaler, who, in a report on the geology of Cobscook Bay,[a] has presented some results of observations made in this very interesting area.

Collections of fossils were made by Professor Shaler: (1) At a point about half a mile south of Balls Mill, on the west side of Whitings, or Orange, Bay; (2) at the head of Leightons Cove; (3) on the east shore of Sewards Neck at Rogers Island and at Reynolds Cove; and (4) at Shackford Head on Moose Island, and at Princess Cove.

From the first of these localities Professor Shaler provisionally lists 33 species of invertebrates, which he interprets as showing contemporaneity with the Lower Helderberg group of New York, although failing to indicate any particular division of that series.

The Leightons Cove fauna, of which he gives a preliminary list of 17 species, he regards as proving a close relation of these beds to the horizons of the Clinton and Niagara in New York.

In the Moose Island material he tentatively identifies 6 species, which are considered by him as supporting a correlation of these rocks with the middle Devonian of Ohio and Kentucky.

The collections of fossils made by Professor Shaler in the Cobscook Bay region have more recently been transferred to the hands of Prof. H. S. Williams, who has been engaged in a special study of the upper Paleozoic faunas of Maine. In response to the request of the chief paleontologist of the Survey, Professor Williams has had the courtesy to review the fossils from the above-mentioned localities and to communicate provisional lists of the species, together with his conclusions as to the age of the fossiliferous beds. In his study of the specimens he has had the assistance of Dr. E. M. Kindle, whose knowledge of and experience in studying Silurian fossils is well recognized.

From the Leightons Cove collection (station 1442) Professor Williams reports 16 species, as follows:

[a] Shaler, N. S., Am. Jour. Sci., 3d ser., vol. 32, 1886, pp. 35–60.

Fossil invertebrates collected at Leightons Cove, Me.

Species.	Reported range.
Lingula sp.	Cambrian-Recent.
Orbiculoidea sp.	Ordovician-Recent.
Strophеodonta? sp.	Silurian-Devonian.
Chonetes cf. hudsonicus.	"Becraft."
Dalmanella cf. planiconvexa.	Lower Helderberg-Oriskany.
Dalmanella cf. subcarinata.	Lower Helderberg.
Rhynchotrema formosum.	Lower Helderberg.
Camarotœchia sp.	Ordovician-Carboniferous.
Trematospira cf. simplex.	Lower Helderberg.
Orthonota? sp.	Silurian-Carboniferous.
Nucula? sp.	Silurian-Recent.
Avicula cf. communis.	Lower Helderberg.
Modiolopsis? sp.	Ordovician-Lower Helderberg.
Tentaculites elongatus.	Lower Helderberg.
Cheirurus sp.	Ordovician-Silurian.
Beyrichia sp.	Ordovician-Carboniferous.

It is the opinion of both Doctor Kindle and Professor Williams that there are not among them "any purely diagnostic Clinton or Niagara species, and though the orthids and strophodontas and some other things are similar to Niagara forms, they are closer to the eastern type of Lower Helderberg species of the same genera."[a]

From the material from Whitings Bay (station 1440) Professor Williams provisionally lists the following 36 species:

Species collected at Whitings Bay, Me.

Species.	Reported range.
Receptaculites infundibuliformis Eaton.	Lower Helderberg.
Zaphrentis sp.	Silurian-Carboniferous.
Spirorbis sp.	Paleozoic-Recent.
Cornulites cf. serpularius.	Ordovician-Silurian.
Monomerella cf. ovata var. lata.	Guelph.
Leptæna rhomboidalis.	Trenton-"Warsaw."
Strophеodonta cf. Beckii.	Lower Helderberg.
Strophеodonta planulata.	Lower Helderberg.
Strophеodonta cf. varistriata.	Lower Helderberg.
Strophеodonta? sp.	Silurian-Devonian.
Chonetes cf. hudsonicus.	"Becraft."
Dalmanella cf. perelegans.	Lower Helderberg.
Dalmanella cf. subcarinata.	Lower Helderberg.
Rhynchotrema formosum.	Lower Helderberg.
Uncinulus mutabilis.	Lower Helderberg.

[a] Letter of May 12, 1904, to Dr. T. W. Stanton.

Species.	Reported range.
Atrypa reticularis.	Silurian-Devonian.
Spirifer cf. octocostatus.	Lower Helderberg.
Spirifer cf. perlamellosus.	Lower Helderberg.
Trematospira cf. simplex.	Lower Helderberg.
Nucula ? sp.	Silurian-Recent.
Tellinomya n. sp.	Ordovician-Lower Helderberg.
Cypricardites n. sp.	Ordovician-Devonian.
Ambonychia cf. aphæa.	Niagara.
Conocardium ? sp.	Ordovician-Carboniferous.
Avicula cf. communis.	Lower Helderberg.
Cyrtolites sp.	Cambrian-Carboniferous.
Cyclonema sp.	Ordovician-Devonian.
Loxonema cf. Fitchii.	Lower Helderberg.
Tentaculites elongatus.	Lower Helderberg.
Hyolithes sp.	Cambrian-Carboniferous.
Cyrtoceras myrice.	Lower Helderberg.
Oncoceras cf. ovoides.	Lower Helderberg.
Proetus sp.	Ordovician-Devonian.
Calymene sp.	Ordovician-Silurian.
Dalmanites cf. micrurus.	Lower Helderberg.
? Fish teeth.	Silurian-Recent.

This list, in the judgment of Professor Williams, contains about the same number of diagnostic Lower Helderberg species as were given by Professor Shaler.

The single species which Professor Williams reports from Sewards Neck (Station 1447) is called *Modiolopsis* cf. *undulostriatus*, a Niagara fossil which, he remarks, "is a form that might occur higher."

Professor Williams appends the following very important and interesting correlations and observations:

"Although the species listed from these three localities are not the same throughout, Mr. Kindle and I agree in thinking them to be younger than typical Niagara and more intimately related to the Lower Helderberg fauna of New York and the interior than to any other fauna of the country yet reported.

"There are many species among them which in general characters have both Niagara and Lower Helderberg representatives, with neither of which they exactly agree, but critical comparison favors the Lower Helderberg correlation.

"The *Monomerella* (No. 5 of the Whitings list) is very close to the Guelph species *M. ovata var. lata* Whiteaves,[a] from Durham, Ontario, Canada. Two specimens are in the collection from Maine. In both the Durham, Canada, and the Cobscook, Me., localities, this species is associated with *Cyrtoceras myrice*.

"It is also important to note that no truly diagnostic Niagara species have been detected after careful search. This distinguishes the fauna from that reported from North Haven, in Penobscot Bay, and from each of the faunas of Aroostook County,

[a] Pal. Foss. (Canada), vol. 3, pt. 1, p. 6, pl. viii, fig. 2a.

Me., which have been referred to the Niagara, namely, 'Aroostook limestone,' 'Graptolite shale,' 'Sheridan sandstone,' 'Ashland' shales and limestone,[a] each of which has shown some true Niagara species.

"On the other hand, although the species are not the same throughout, there are enough common forms to associate these Cobscook formations with the 'Squaw Lake limestone' and 'Chapman sandstones' in Aroostook County, and with the 'St. Helens beds' of Canada, as all belong to approximately the same general place in the time scale. The Cobscook faunas seem to me to be somewhat older than the typical Lower Helderberg taken as a whole, and particularly older than the other three eastern faunas above named."

In his preliminary list of the fossils collected by Professor Shaler from Moose Island Professor Williams makes no distinction as to the two or three localities. The species enumerated are as follows:

Species collected at Moose Island, Me.

Species.	Reported range.
Lingula cf. ligea.	Middle-upper Devonian.
Orthis sp.	Ordovician-Carboniferous.
Camarotœchia sp.	Ordovician-Carboniferous.
Atrypa reticularis.	Silurian-Devonian.
Spirifer ? sp.	Silurian-Carboniferous.
Cyrtina ? sp.	Silurian-Carboniferous.
Nyassa subalata.	Hamilton.
Modiomorpha cf. subalata var.	Hamilton.
Murchisonia sp.	Cambrian-Trias.
Beyrichia sp.	Ordovician-Carboniferous.

Professor Williams writes:

"The Moose Island fauna is very perplexing, as it contains nothing which, so far as I am able to see, can be taken as absolute evidence of Devonian. The genera reported are all long-ranging Paleozoic forms, and on account of the distortion of the beds it is impossible to establish with certainty the specific characters of most of them. We have identified *Nyassa subalata* and a *Lingula* as *L.* cf. *ligea*, and a very common fossil as *Modiomorpha subalata*. These are all Devonian, and although I think the fauna is probably Devonian, I would not be surprised to find, on more careful study and on the discovery of more species, that it is Carboniferous. Provisionally, and until further study and full comparison can be made with Nova Scotia, English, Welsh, and European faunas, the first three faunas may be correlated with those of the early Lower Helderberg time, and the fourth fauna may probably be assigned to middle Devonian time, its exact horizon being uncertain."

It will be seen that Professor Williams's opinion regarding the fossiliferous beds on Moose Island differs to an important extent from that based by Mr. Schuchert on the very small collections which were made by the writers at other points on

[a] Williams, H. S., and Gregory, H. E., Contributions to geology Maine: Bull. U. S. Geol. Survey No. 165, 1900, pp. 44–54.

Moose Island, but which probably represent, in part at least, the same series of rocks.

The rocks in which the faunas from the three localities first mentioned were collected were grouped together by Professor Shaler and termed the "Cobscook series," while the rocks supposed by him to be Devonian are named the "Moose Island series." Messrs. Bailey and Matthew earlier described[a] these same rocks under the name of "Mascarene series," which was believed to measure about 2,000 feet in thickness.

As stated above, the Perry formation at the northern end of the basin is in contact with the granite; at the southern end it overlies strata that are believed to belong to the "Cobscook series" of Shaler and the "Mascarene series" of Bailey and Matthew. Closely associated with these sedimentary strata are volcanic rocks which will be described in a later section.

Inasmuch as no sections of the Silurian rocks were measured or carefully studied, only a general description of them can be given here. On the northern part of the Pleasant Point peninsula the more important members of the sedimentary formation are dark-gray flags, which usually show ripple marks and contain abundant impressions of brachiopods. Shales and fine-grained impure limestones also occur in this section, while similar rocks were observed on the western shore of the cove west of this peninsula. The general strike of these rocks is N. 25° to 80° E., and their dip is northwest, at angles ranging from 35° to 75°.

On Birch Point, on the north side of Cobscook Bay, similar ripple-marked flags, shales, and impure limestones occur, striking N. 30° E. and dipping 30° to the north.

In the western part of the area described in this report is a considerable thickness of purple shales, extending from the head of Sipp Bay westward to Pennamaquan River at Pembroke, where they are succeeded by dark, fossiliferous slates and sandstones. The belt of purple shales extends a mile or two up Pennamaquan River, and the shales are remarkably uniform in character wherever seen and show a fairly constant dip to the northeast. Professor Shaler provisionally assigned these purple shales to the Perry formation, apparently upon the basis of color and relations to the beds of the Cobscook series.[b] Bailey and Matthew[c] describe the same rocks, but place them in the next to the uppermost division of their "Mascarene series." That these shales belong to the pre-Perry formation is indicated both by their areal position and stratigraphic relations to the fossiliferous strata at Pembroke and on Cobscook Bay and by their lithologic differences from the Perry rocks. In the Perry section there are no shale beds that can be compared with these, the thickness of which Shaler estimates as over 1,500 feet. The purple shales are finer grained than the Perry rocks, have

[a] Geol. Survey Canada, Rept. 1872, pp. 144–158. [b] Am. Jour. Sci., 3d ser., vol. 32, 1886, p. 49. [c] Op. cit., p. 157.

a different color, and, moreover, show slaty cleavage, a structure not observed in any of the shaly beds in the Perry section. These purple shales do not come into contact with the Perry formation, but dip beneath a mass of volcanic rocks that underlie the Perry formation. Interstratified with these volcanic rocks, however, is a bed of similar purple shale, which lies unconformably beneath the Perry rocks. From these considerations it is believed that the purple shales also are to be included in the series regarded as Silurian.

A small number of invertebrate fossils were collected by the writers in 1903 from several localities in the vicinity of Perry. All these fossils, with the exception of a few fragments from Mr. Farnsworth's yard at West Pembroke, come from the Moose Island series, which, as we have seen, is regarded by both Shaler and Williams as probably Devonian. These small collections were placed in the hands of Mr. Charles Schuchert, curator of paleontology in the United States National Museum, who has submitted a report upon them as follows:

"1. Carlow Island, St. Croix River, Maine:

"Lingula sp. new.
"Whiteavesia sp. new.
"Bollia near B. Clarkei.
"Leperditia of the L. alta type.
"Beyrichia, two species, one of the B. Klödeni type.
"Bythocypris, probably two species.

"This fauna is unmistakably Siluric and beneath the Helderbergian. As all of the species appear to be new, no direct comparison can be made with Appalachian and Interior faunas. In general the aspect of this fauna reminds one of the Medina and Manlius; and while it certainly is not so low as the former, it does not appear to be so high as the latter. Provisionally it should be referred to the Niagaran (i. e., Rochester shale and Lockport limestone of the Interior), as it has nothing in common with the Helderbergian faunas of the Cobscook region.

"2. Inlet south of Little River, 2 miles from Perry village, Me.:

"Lingula sp. new.
"Whiteavesia sp. new.
"Modiolopsis sp. undetermined.

"Apparently the same horizon as at Carlow Island.

"3. North end of Moose Island, 3 miles north of Eastport, Me.:

"Psiloconchoid pelecypod.
"Bythocypris, probably the same species as the one found at Carlow Island.
"Beyrichia, species restricted to this locality.

"This fauna has nothing that can be certainly identified with that of Carlow Island, and yet its characteristics are Siluric. It probably indicates the same age as that of Carlow Island.

"4. A. S. Farnsworth's yard, West Pembroke, Me.:

"Brachiopod, possibly a rhynchonelloid.
"Tentaculites.

"Age uncertain, possibly Siluric.

"5. Pleasant Point, 4 miles northeast of Eastport, Me.:

"A small, distorted, and poor bivalve; may be modiolopsoid."

Although it is possible that none of the localities mentioned above are representative of Professor Shaler's collections, and consequently are not in the lists given by Williams, it appears probable that the specimens from localities Nos. 1, 2, 3, and 5 are derived from the "Moose Island series," as defined by Professor Shaler. The testimony of the stratigraphy, so far as observed by the writers, as well as the correlations made by the Canadian geologists, tend to confirm the assignment of the series to the Silurian.

No attempt has been made to represent on the geologic map the exact distribution of the Silurian strata. They are intimately connected with the volcanic rocks, and detailed study would be necessary to work out the structure. It is sufficient for the present purpose to observe that wherever these rocks are in contact with the Perry formation the relations are seen to be unconformable.

ASSOCIATED LAVAS.

A large proportion of the rocks in contact with the Perry formation are of volcanic origin. In part these are closely associated with the Silurian sediments, but elsewhere the lavas predominate. Doubtless these pre-Perry lavas may include several types, but only those occurring in the southern part of the town of Perry were examined.

South of Gleason Cove these volcanic rocks are exposed both in the railroad cut and along the shore. Two types were recognized in the field, the dark, compact lava, exhibiting flowage texture, and the breccia, in which fragments of similar lava can be seen. Later microscopic study has verified this recognition of the rocks as of volcanic origin and has shown them to be of rhyolitic composition. Quartz and orthoclase are sporadic constituents in the rhyolite, and the fluidal texture in the glassy base, now for the most part devitrified, is conspicuous. In the brecciated phase of lava, fragments of clear glass are included in darker glass. This rhyolite has special interest because of its connection with the drill core mentioned in a later portion of this report. Some coarse agglomerates are associated with the rhyolite.

Farther south, on Carlow Island, there is a red porphyritic rock which appears to be interbedded with the sedimentary strata. This rock extends around the north end of Moose Island to the toll bridge. When examined microscopically it is found to be in large part a spherulitic lava. The spherulites are much altered and brightly colored with a red pigment, probably oxide of iron. Quartz occurs in large grains inclosing the spherulites, while what was probably orthoclase, now altered, forms phenocrysts at the center of a few spherulites. Another phase of this red rock is

found to be fragmental and composed of angular particles of quartz, orthoclase, plagioclase, and spherulitic lava.

In the rough and hilly region southwest of the village of Perry more spherulitic lava is associated with a purple shale. The spherulites are readily seen on the weathered surface of the pinkish rock. Under the microscope this rock is seen to be a fine type of spherulitic lava. The spherulites exhibit both radial and zonal structures, and the radial crystallization, in the interior at least, is primary, while the fine quartz and feldspar mosaics in the outer zones may be possibly of secondary origin. There are also some fragments of pink glass, with delicate trichites.

These rhyolitic lavas were termed "reddish felsite" and "felsite porphyry" by Shaler, and their occurrence was described by him as that of extrusive flows with associated dikes. These "felsites" were assigned by Bailey and Matthew to the "Mascarene series," forming division 5 of that series. In addition to recognizing the pre-Perry age of these rhyolitic lavas, which is most conclusively shown by the pebbles found in the Perry conglomerate, it is only necessary to call attention to the marked differences between these rhyolites and the lavas described later as included in the Perry formation.

PERRY FORMATION.

SUBDIVISION.

The Perry formation as exposed in the towns of Robbinston and Perry is divisible into four members. Two of these members consist of sedimentary strata, while the other two are interbedded lavas and associated volcanic breccia. The section may be described thus:

Members of Perry formation.

Upper lava: Green lava with columnar parting and amygdaloidal texture. Includes one bed of conglomerate and sandstone.

Upper sandstone: Coarse red and brown sandstone and conglomerate, with small amounts of shale. Includes one flow of lava near base.

Lower lava: Basaltic lava and breccia. Includes one thin bed of conglomerate near top.

Lower conglomerate: Coarse conglomerate and red sandstone, with thin beds of sandy shale.

The thickness of these members can not be definitely given. The lowest member is evidently the thickest, but probably its thickness varies considerably in different parts of the area. As will be noted later, the Perry sediments were largely shore deposits, so that the distance from the source of the material would control largely the thickness of the beds. In the case of the volcanic members the different lava flows give the impression of being rather more persistent in thickness than might be expected. The faulting in the southern part of the area of course precludes any comparison of thickness in the different parts of the shore section.

OCCURRENCE.

The rocks of this formation are exposed continuously along the shore from Mill Cove, in the southern part of Robbinston, to Gleason Cove, in the town of Perry. A smaller area of the same formation occurs farther south in Perry, on the shore of Bar Harbor, at the northern end of the highway bridge. Another outlier of these rocks occurs on the shore in the northern part of the town of Robbinston.

As shown on the geologic map, the area covered by the Perry formation is about 8 miles long and about 2½ miles wide at its widest part, its total area being about 15 square miles. The Perry rocks occur on the opposite shore of St. Croix River, at St. Andrews, and their occurrence farther west on the Maine coast was reported in the early surveys. The Perry area, however, is doubtless of most importance, not only on account of the flora it has yielded, but also because the formation is apparently more fully represented here than farther east.

The lower conglomerate member occupies the larger part of the area here described. The northern outlier of Perry rocks is north of Hilchins Point, a connected tongue making up the shore of Brooks Cove. In the northernmost portion of this outlier the Perry conglomerate occurs with a dip of 20° to the southeast, while just north of Hilchins Point the conglomerate and sandstone have a northern dip of 30°. The basal beds here and at Brooks Cove are coarse, and at the latter locality especially the conglomerate exhibits its derivation from the red granite of the vicinity; the bowlders of that rock predominate, and the matrix is of an arkose character.

In the larger area the conglomerates predominate in this lowest member, but it appears to be true that the beds are of somewhat finer material in the southern part of the area than in the northern. The sandstone beds are massive and resist well the attacks of the waves, so that a high cliff is a characteristic shore feature. Pulpit Rock is a noticeable mass of red sandstone standing out at a little distance from the cliff, and was pictured in the atlas accompanying Jackson's first report.

Throughout the shore section the rocks of this lower member are characterized by their red color, which varies from a bright brick red to a chocolate brown, although the brighter tints are possibly the more common. While this red color is so marked a feature, it can not be regarded as a safe criterion for the recognition of the Perry formation. The Perry sandstones and conglomerates share this color with older formations, from which they have been derived. So it is that at a short distance the red granite and lava underlying the Perry conglomerate in Robbinston or on the shore of Bar Harbor closely resemble the Perry rocks. The shore detritus from these igneous rocks that is seen along St. Croix River often can not

be distinguished from that derived from the disintegration of the red sandstone or conglomerate. Moreover, this close resemblance is not fortuitous, since in the deposition of the Perry rocks it was in fact exactly similar shore detritus from the red granite and lava that made up the bulk of the sediments. The rocks of the Perry formation, therefore, are red because they were largely derived from red rocks, under conditions that allowed relatively little change in the detritus contributed to the basin of sedimentation.

The Perry rocks exposed on the St. Andrews Peninsula, on the New Brunswick shore, appear to belong to this lowest member of the formation. It is evident, however, that here the sandstone and shale are more important than the conglomerate. Such differences in the character of beds of approximately the same age are to be expected in the case of a formation like the Perry, which consists essentially of shore deposits. The Perry rocks occurring in small areas at other points on the shores of Passamaquoddy Bay probably all belong to this lowest member.

The next higher member of the Perry formation is that termed the lower lava in the table on page 28. This volcanic member is exposed from Gin Cove to a short distance beyond the next cove south.[a] These same rocks are also exposed on the shore about half a mile north of Gleason Cove. These rocks are plainly of volcanic nature, the member including sheets of both lava and breccia. The lava exhibits all the characteristics of a surface flow and the succession of flows and sheets of breccia make a striking contrast to the stratified sediments below. The volcanic rocks are evidently conformable with the sedimentary strata both above and below; at one place a thin bed of typical conglomerate occurs, interstratified with the lava flows, and at another some fine-grained red shale occurs, noticeable since it is less arenaceous than any beds farther north. Thus the volcanic member represents simply an interval in the deposition of the Perry sediments, probably only of short duration, when the lavas were erupted; and the occurrence of the thin conglomerate shows that this outbreak constituted only a partial interruption of the processes of sedimentation.

The lavas constituting this volcanic member are different from the Silurian lavas described earlier in this chapter. The Perry lavas appear much fresher and are more readily recognized as the products of volcanic action. Not only do they lack the metamorphism of the Silurian rocks, but they are of a different type. The lava exposed in the vicinity of Gin Cove is a purple basalt. Examined microscopically it is found to consist of plagioclase in fine laths and augite in large ophitic plates. Dark reddish brown iddingsite is present, and probably represents grains of olivine, which must have been an important constituent in

[a] The name Gin Cove is applied on the accompanying map to the cove locally so known, although this usage does not agree with the coast chart, on which this name is given to the next cove southward.

the fresh lava. Magnetite is also abundant. With the exception of this alteration of what was probably olivine, the basalt is fairly fresh for a Paleozoic lava.

The upper sandstone member conformably overlies the basaltic rocks just described. This division of the Perry formation is exposed on the shore north of Frost Cove. Its lowest bed consists of conglomerate and coarse sandstone about 50 feet thick. Above this is a sheet of volcanic rock about 30 feet thick, which is undoubtedly a lava flow, as the rock is compact and shows imperfect parting in its lower portion, while above it is amygdaloidal and exhibits flowage textures. It is followed by a number of beds of sandstone and conglomerate. The sandstone is for the most part thin bedded and the beds are not always continuous for any distance. Small amounts of shale occur interbedded with the sandstone. Some of the sandstone is stream bedded, and in such rock it is noticeable that the flow of the currents depositing the sand is shown always to have been from the northwest. At the top of this upper sandstone member is a conglomerate bed 6 to 8 feet in thickness.

The upper lava member is exposed for a short distance south of Frost Cove and constitutes the remaining portion of this section of the Perry formation. This lava is dark green in color and apparently similar in composition to the basalt of the lower member, but it is not so compact, and possibly may be more andesitic in character. Some phases of the rock have a decidedly muddy appearance and may represent flows containing considerable fragmental material. The lava exhibits both columnar parting and amygdaloidal texture, so that it is readily recognizable as a volcanic rock. At one point this volcanic member includes a few feet of conglomerate and red sandstone, showing again how intimately connected were these volcanic outflows with the processes of sedimentation, the one interrupting the other only for brief intervals. On this account the subdivision of the Perry formation into these four members is somewhat arbitrary, and is helpful only as it serves the purposes of description. The representation of these four subdivisions on the geologic map makes it possible to indicate the general structure of the area.

GENERAL CHARACTERS.

The above descriptions of the rocks of the Perry formation are believed to be sufficient to indicate the general characters of the rocks in which the search for coal has been prosecuted. The more important question of the age of this formation is reserved for another chapter of this report.

Two principal facts should be emphasized in the description of the Perry formation, namely, the difference in character of the sediments in the several parts of the area, and the absence of carbonaceous or clayey beds in the section exposed.

The changing characters of these Perry rocks is an evident expression of the conditions of their deposition. The greater distance of the Gleason Cove locality and St. Andrews Point from the main source of supply caused conglomerate beds at these places to be thinner than at places farther north and west. At this greater distance the sediments consisted largely of sands and silts that formed the sandstones and sandy shales now exposed. These sediments were well sorted, and so active were the shore currents that plainly at no time were the conditions such as to favor the accumulation of fine mud or vegetal matter. It is not altogether surprising, therefore, that fine clays or coaly shales are wanting in the sections of the Perry formation.

Still another important fact remains to be mentioned, and this pertains to the volcanic members of the Perry formation. The lavas interbedded with the sedimentary rocks of this formation differ altogether from the lavas associated with the Silurian strata. These two groups of volcanic rocks may have some points of general resemblance, but to the close observer they appear quite distinct, and their petrographic dissimilarity is especially evident when they are studied microscopically. The distinction between the Silurian rhyolite and the Perry basalt is so marked that there is no possibility of failure to identify each wherever found. This fact was recognized in the field and its application to the purposes of this investigation will be noted in a later section.

STRUCTURE.

The geologic map well exhibits the structure of the Perry basin. In general it may be stated that the rocks of the Perry formation are only gently inclined, 15° to 20° being the maximum dip except for a short distance north of Gleason Cove. Low dips are also characteristic of the Perry rocks as exposed on the St. Andrews shore. The general statement may be made, therefore, that the rocks of this formation are only gently flexed.

The areal distribution of the four members which are distinguished on the geologic map serves to show the general form of the basin so far as the Maine portion is concerned. It is really only the western part of the basin that is preserved on this southeastern shore of Maine. Other edges are found on the New Brunswick shores, but the central portion is beneath the waters of Passamaquoddy Bay. It seems probable, however, that the greater part of the formation is represented in this western part of the basin. The smaller area of Perry sandstone west of Bar Harbor, in the southern part of the town of Perry, has low dips, and the small thickness of rock exposed here shows that outliers of this formation may perhaps occur still farther southwest, and these may later be found to connect this basin with the Machias area of red sandstones described in the early Maine reports.

The heavy sandstones of the Perry formation are plainly jointed. In many places the vertical joint planes have been taken advantage of by surface waters and deep chasms have been thus eroded. These breaks in the cliff are conspicuous, but are plainly the product of erosion, there being no displacement of the strata on either side. In some cases wave erosion has combined with the work of surface rivulets and considerably enlarged these openings. Pulpit Rock was probably separated from the main cliff by erosion of this type.

Faulting has played some part in the development of the structure. In the southern part of the area two faults were observed and their positions are indicated on the map. These faults both have a general east-west trend, and while definitely observed at the shore, their extent farther west was not determined. Their extension, as shown on the map, is based upon observations as to the distribution of the rocks. As may be noticed on the map, two marked offsets in the basal boundary of the Perry formation are in line with these faults. No evidence of faulting was noticed at these offsets and the suggestion is offered that in passing westward the faults become sharp monoclinal flexures, which find expression in the sharp bends in the Perry-Silurian contact.

The more northern of the two faults brings the upper lava member on the north in contact with what is probably the upper sandstone member. The fault plane is vertical and the sandstone, which shows a normal dip to the southeast at an angle of 20°, is sharply upturned until it is vertical or even slightly overturned at the contact with the lava, which is itself disturbed at the line of contact. These relations show the downthrow to be on the north side of the fault, but there is no reason for believing the displacement to be very great.

The other fault strikes N. 70° E. and brings what appears to be the lower lava in contact with the lower conglomerate member. Here again it does not seem probable that the amount of displacement is great, although there are evident indications of disturbance in the vicinity of this fault. The sandstone strata immediately south of the fault have been thrown into sharp folds, and the axes of the folds nearest the fault have a trend parallel to that of the fault plane. A minor syncline next to the fault is overturned and at the fault contact both sandstone and lava are crumpled and crushed.

Further evidence of the disturbed character of this south side of the main syncline is found in the continuance of the steep dips along this shore as far as the mouth of Little River. Here the sandstone has a dip of 50° to the north, while on the opposite shore of Gleason Cove the more prevalent dip of 20° is observed.

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Another fault was noted at the head of the long cove south of Gleason Cove. A westward extension of the Perry conglomerate here overlies the Silurian flags, with a low northern dip. A short distance farther north the conglomerate has its dip steepened and is then abruptly cut off by the Silurian lava. At the contact the lava shows a slickensided surface. This fault differs from the two before described in that here the downthrown block is on the south side of the fault. Doubtless other faults exist in this area, but these are the more important ones, the others being too small to be detected in this rapid survey of the section.

CHAPTER III.

PALEONTOLOGY.

By David White.

No fossil remains of animals have yet been recognized in the Perry formation. Fragments of stems or algæ are found in many of the beds that are of sufficiently fine composition to preserve or reveal them, but such beds constitute a very small part of the formation. The plant remains found consist chiefly of broken and waterworn stems, generally so fragmentary and abraded that they can not be identified paleontologically, or used to determine questions of stratigraphy.

PLANT-BEARING LOCALITIES.

The discoveries of recognizable land plants are confined essentially to two localities in different horizons in the lower divison of the formation. Descriptions of these places are given in considerable detail by Dawson in his earlier papers. Most of the fossils from the formation are said to have come from a thin stratum of green, sandy shales[a] outcropping on the right bank of Little River, about one-half mile below the wagon-road bridge at Perry. This thin bed, which is described as a green-shale lens, is stated by Dawson[b] to have been worked out and exhausted by 1863. We were, however, so fortunate in 1903 as to find and to uncover the edge of this lentil and to obtain considerable material, though in excellence if not in variety it is inferior to some of that collected in larger quantity in earlier years by Mr. Jethro Brown, a systematic as well as an arduous collector at Perry, and by Dawson, Hitchcock, Richardson, the Rogers Brothers, and other geologists who visited this region. A second locality is on the Robbinston road about one-half mile north of the Perry post-office, where, near McPhail's house, red sandy shales and red sandstones with land plants occur just above the lava sheet on which the road runs.

[a] This is one of the extremely rare occurrences of green-shale parting, green-shale strata being almost unknown in the Perry formation.

[b] Quart. Jour. Geol. Soc. London, vol. 19, p. 460.

Other plant remains, consisting for the most part of fragments of stems such as have generally been referred to *Psilophyton*, are found at various places in the more southern outcrops, while fragments of algæ are not rare in the less conglomeratic beds along Little River and near the fault north of Gleason Cove.

COLLECTIONS STUDIED.

The task of restudying the old as well as the new collections, necessary to a critical examination of the evidence as to the age of the Perry beds, has been very difficult by reason of the unfortunate dismemberment and dispersal of the earlier collections, which included many of the types. It is believed, however, that in the preparation of the following descriptions the greater part of the Perry material existing in our American museums has been passed in view. Special acknowledgments are due the officers of the Portland Society of Natural History, to Dr. E. O. Hovey and the American Museum of Natural History, to Prof. C. W. Johnson and the Boston Society of Natural History, and to Dr. R. T. Jackson and the Museum of Comparative Zoology of Harvard University for generously placing at my disposal the fossil plants from Perry in these institutions; also to General Manager Evans of the Maine Central Railway, and Mr. Jackson Brown, of Perry, for the contribution of specimens more recently collected by the latter. We are also particularly indebted to Prof. D. P. Penhallow, of McGill University, Montreal, for his courtesy in placing in my hands for examination and comparison typical *Psilophyton* material from the university collections studied and labeled by Sir William Dawson.

DESCRIPTIONS OF SPECIES.

On account of the generally very fragmentary nature of the fossil materials and the equally fragmentary literature on Devonian plants the descriptions and synonymy in the following section are somewhat detailed, a number of the specimens being described individually in order that these rare Devonian types, many of which are at best difficult of interpretation, may be more accurately as well as more frequently recognized and identified.

Concerning the botanical relations and structure of many of the types of this period we have little knowledge. Yet many of the fragments of stems, foliage, or problematic fructifications reveal superficial features and peculiarities of form which distinguish them from the plant types of other geologic times and thus render them characteristic of the period.

TÆNIOCRADA D. White.

Rept. State Paleont., New York, 1902, p. 603.

TÆNIOCRADA PALMATA D. W.

Pl. II, Fig. 10.

Frond small, spreading broadly palmately from the apex of a slender, rounded stipe, deeply dissected, nearly to the base, in divisions 2–3 mm. wide, which fork repeatedly and somewhat divaricately at a moderate angle, at intervals of about 5 cm.; lobes fleshy, smooth, rapidly diminishing in width at each dichotomy; central strand or axis indistinct.

The alga described above is essentially characterized by the palmate arrangement of the rapidly dichotomising lobes at the apex of a stipe. In the specimen figured, Pl. II, Fig. 10, the stipe is concealed for a short distance, when the cleavage of the rock shows its continuation to a length of 3 cm. on the opposite side of the shale fragment. The lobes appear to have been somewhat crowded or fasciculate in the middle of the frond. As indicated by the smooth surface of the impression and a slight slickensiding near the base, the lobes were probably fleshy. In the basal portions there are faint signs of axial strands, but these become indistinct on passing upward. It is possible, however, that better preserved specimens will show this plant to possess well-developed axial strands, thus removing all doubt as to the reference of the species to the genus *Tæniocrada*.

The specimen comes from just east of the fault west of Gleasons Cove, near the mouth of Little River.

PLATYPHYLLUM Dawson.

Foss. Pl. Erian and Upp. Sil. Form. Can., pt. 2, 1882, p. 101.

PLATYPHYLLUM BROWNIANUM Dn.

Pl. II, Figs. 1, 2.

1862. *Cyclopteris Browniana* Dawson, Rept. Nat. Hist. and Geol. Me., 1861, p. 250, fig. 5.
1862. *Cyclopteris Browniana* Dn., Hitchcock, Rept. Nat. Hist. and Geol. Me., 1861, p. 248.
1862. *Cyclopteris Browniana* Dawson, Proc. Portland Soc. Nat. Hist., vol. i, pt. 1, p. 77, pl. i, fig. 3.
1862. *Cyclopteris Browniana* Dawson, Quart. Jour. Geol. Soc. London, vol. xviii, p. 320, pl. xii, fig. 9.
1863. *Cyclopteris Browniana* Dawson, Am. Jour. Sci., 2d ser., vol. xxxv, p. 313.
1863. *Cyclopteris Browniana* Dawson, 2d Ann. Rept. Nat. Hist. and Geol. Me., 1862, p. 403.
1863. *Cyclopteris Browniana* Dawson, Proc. Portland Soc. Nat. Hist., vol. i, pt. 2, p. 100, pl. ii, fig. 5.
1863. *Cyclopteris Brownii* Dawson, Quart. Jour. Geol. Soc. London, vol. xix, p. 463, pl. xvii, fig. 6.
1871. *Cyclopteris Brownii* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 46, pl. xv, fig. 172, p. 85.
1877. *Cyclopteris Brownii* Dn., Peach, Trans. Geol. Soc. Edinb., vol. iii, p. 151.
1883. *Cyclopteris Brownii* Dawson, Can. Nat., vol. x, No. 1, p. 10.
1888. *Cyclopteris Brownii* Dawson, Quart. Jour. Geol. Soc. London, vol. xxxvii, p. 307.

1882. *Cyclopteris* (*Platyphyllum*) *Brownii* Dawson, Foss. Pl. Erian and Upp. Sil. Can., pt. 2, p. 101, pl. xxiii, figs. 11–13 (?).

1884. *Archæopteris* (*Cyclopteris*) *Brownii* (Dn.) Lesquereux, Coal Flora, vol. iii, pp. 837, 850.

1886. *Palæopteris* (?) *Brownii* (Dn.), Kidston, Cat. Pal. Foss. Pl. Brit. Mus., p. 229.

1888. *Platyphyllum Brownii* Dawson, Geol. Hist. Pl., p. 265.

1889. *Rhacophyllum Brownii* (Dn.) S. A. Miller, N. Amer. Geol. and Pal., p. 139.

1894. *Cyclopteris* sp., Nathorst, Zur. Pal. Fl. d. Arkt. Zone, pt. 1, Lief. 1, p. 13, pl. 1, fig. 12.

Fronds or pinnules large, often 15 cm. or more in length, more or less orbicular, obovate, or ovate, deeply and often broadly cuneate-lobate, sinuate margined, membranaceous; nerves very thin, obscurely if at all fibrous, distant about 2–3 mm. midway of the leaf, and forking four or five times in passing, gently arching, to the margin.

Little is known as to the precise affinities of this interesting species, which was named for Mr. Jethro Brown, the original collector at Perry, the type locality. The small fragments collected in 1903 agree in all respects with that figured in pl. ii, fig. 5, of vol. 1, pt. 2, of the Proceedings of the Portland Society of Natural History, 1863, and which, through the courtesy of the Boston Society of Natural History, we are able to reproduce in Pl. II, Fig. 1. Sir William Dawson, in his later observations,[a] was disposed to regard these fossils as either epiphytic on fern stems or as growing in clusters from rhizomes. The latter view is based on the specimens from Scaumenac, which were erroneously, I believe, identified with this species. As to their fern nature, I would add that in the State paleontological collections at Albany I have seen large cyclopterid pinnules superficially resembling these on the rachis of large petioles taken from the Chemung, near Hancock, N. Y., and probably belonging to *Archæopteris obtusa* (Lx.).

It seems possible, however, that the plant in hand is to be assigned to the Algæ, to which the fragments before me appear to be bound by the characters of the membranaceous lamina and by the thin nerve bands, which are evidently thickened as compared with the intervening lamina, but which, to my mind, do not show indisputable signs of fibro-vascular structure. In this respect they are in exact agreement with the type[b] described by Lesquereux[c] as *Rhacophyllum truncatum*, which was considered by both its author and Sir William Dawson as probably identical with the plant from Perry. I had collected a number of similar specimens from the Catskill of northeastern Pennsylvania, all of which are apparently algoid, but hesitated to refer them to *Platyphyllum* on account of their more dissected fronds, until opportunity was given me, through the courtesy of the Portland Society of Natural History, to examine its collections, in which I found the highly divaricate specimen illustrated in our Fig. 2. I do not, however, regard *Platyphyllum truncatum* as specifically identical with the Perry species, though it is evidently very closely related to it.

[a] Canadian Naturalist, vol. 10, No. 1, 1883, p. 10.
[b] Lacoe collection, No. 19414, U. S. Nat. Mus.
[c] Coal flora, vol. 1, 1880, p. 311, pl. 1, fig. 7.

The nerves of *Platyphyllum Brownianum* fork four or five times at a rather wide angle, as is well shown in Pl. II, Fig. 2, which shows one of the types. The earliest figured specimen,[a] though a mere morsel from the interior of a leaf, reveals an identical nervation. The statement that the nerves fork but once, made in all of Dawson's descriptions, and illustrated in all other figures of the plant, is wholly erroneous. The specimen from Scaumenac, figured by Dawson as *P. Brownianum*, can not, if drawn correctly, be regarded as representing this species, since the nerves, as shown in the figure, are very much closer, rarely forking, and parallel. None of the Perry specimens show nervation of this type in any portion of the frond.

The fronds obtained from the Catskill of Pennsylvania and regarded as gymnospermous in Rogers's Geology of Pennsylvania, 1858, vol. 2, pl. xxii, can not safely be included in *Platyphyllum Brownianum*, though they are evidently closely related and are no doubt congeneric. Comparison of the Pennsylvania figures, which I will designate *Platyphyllum Rogersi*, should be made with our Fig. 2.

The specimen from the Devonian of the west coast of Spitzbergen, figured by Nathorst,[b] agrees so well with the fragments of the Maine plant that, notwithstanding the insufficiency of the material, I hardly hesitate to place it under the same name.

ARCHÆOPTERIS Dawson.

Foss. Pl. Dev. and Upper Sil. Form. Can., 1871, p. 48.

ARCHÆOPTERIS JACKSONI Dn.

Pl. III, Figs. 1, 2, 2ª, 3, (4?).

1861. *Cyclopteris Jacksoni* Dawson, Can. Nat., vol. vi, No. 3, pp. 172, 173, figs. 9, 9a, 9b.
1862. *Cyclopteris Jacksoni* Dn., Hitchcock, Rept. Nat. Hist. and Geol. Me., 1861, p. 248.
1862. *Cyclopteris Jacksoni* Dawson, Proc. Portland Soc. Nat. Hist., vol. i, pt. 2, p. 76.
1862. *Cyclopteris Jacksoni* Dawson, Quart. Jour. Geol. Soc., vol. xviii, pp. 298, 319.
1863. *Cyclopteris Jacksoni* Dawson, Am. Jour. Sci., 2d ser., vol. xxxv, p. 313.
1863. *Cyclopteris Jacksoni* Dawson, 2d Rept. Nat. Hist. and Geol., Me., p. 402.
1863. *Cyclopteris Jacksoni* Dawson, Quart. Jour. Geol. Soc., vol. xix, p. 462, pl. xix, figs. 26, 26a–c.
1868. *Cyclopteris Jacksoni* Dawson, Acad. Geol., p. 547, figs. 191a, 191b.
1891. *Cyclopteris Jacksoni* Dawson, Geol. N. S. and N. B., p. 546, fig. 191.
1870. *Cyclopteris* (*Archæopteris*) *Jacksoni* Dawson, Nature, vol. ii, p. 87, fig. 3.
1871. *Cyclopteris* (*Archæopteris*) *Jacksoni* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 45, pl. xv, figs. 167–169, p. 85.
1871. *Archæopteris Jacksoni* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 48.
1880. *Archæopteris Jacksoni* Dawson, Chain of Life, p. 98, fig. 89.
1881. *Archæopteris Jacksoni* Dn., I. C. White, Rept. 2d Geol. Surv. Pa., G5, pp. 63, 187.
1882. *Archæopteris Jacksoni* Dn., I. C. White, Rept. 2d Geol. Surv. Pa., G6, pp. 103, 320.

[a] Rept. Nat. Hist. and Geol. Me., 1861 (1862), p. 250, fig. 5.
[b] Fossile Flora der arktischen Zone, pt. 1, lf. 1, pl. 1, fig. 12.

1883. *Archæopteris Jacksoni* Dawson, Can. Nat., vol. x, No. 1, p. 307.
1888. *Archæopteris Jacksoni* Dawson, Geol. Hist. Pl., p. 74, figs. 24, 24a, 24b.
1894. *Archæopteris Jacksoni* Dn., Prosser, Bull. U. S. Geol. Survey No. 120, pp. 13, 14.
1895. *Archæopteris Jacksoni* Dn., Dana, Man. Geol., 4th ed., pp. 592, 622, figs. 898, 899.
1897. *Archæopteris Jacksoni* Dn., Dun, Rec. Geol. Surv. N. S. Wales, vol. v, pt. 3, p. 120.
1880. *Archæopteris Halliana* (Göpp.) Lesquereux, Coal Flora, vol. i, p. 305, syn. in part only.

Fronds sometimes of large size, with thick, striate, or rugose-striate, sometimes obscurely transversely corrugated rachis; lateral pinnæ close, relatively short, occasionally attaining a length of over 12 cm., straight or more commonly curving slightly outward, oblong-linear, tapering but slightly, abruptly obtuse, open or oblique, alternate to opposite, with intermediate alternating pinnules, usually not in the same plane, on the main rachis; pinnules varying in size, relatively oblique, broadly imbricated, rather broadly and decurrently attached, narrowly rhomboidal, the lower proximal margin nearly straight or slightly concave for about one-half the length of the pinnule, the inner distal border nearly straight and vertical for about one-third of the length of the pinnule, then gradually curving outward, the upper half of the pinnule being strongly asymmetrically ovate, and more or less narrowly rounded at the apex, and entire or faintly denticulate; nervation thin, from three or four very obliquely decurrent or coalescent basal nerves, forking three to five times at a very acute angle, while passing nearly parallel with very slight but increasing curvature, at about 40–45 per centimeter, to the margin, which they meet very obliquely; fertile pinnæ borne alternately at the base of the frond, short, much reduced, probably without sterile pinnules at their bases, and alternating on the same side with slender rudimentary or laciniate rachial pinnules; sporangia small, apparently brevipedicellate, erect, oblong, or slightly clavate, narrowly rounded at the apex, probably stalked or borne on reduced nervilles near the base of the pinnæ, though seemingly arranged in a single row along the midrib in the distal portion of the pinna.

The more conspicuous characters of the species described above are the closely placed dense and very obtuse pinnæ, on which the rather broadly overlapping pinnules are rather narrow and are somewhat narrowly as well as obliquely rounded at the apex, the inferior proximal margin being long and nearly straight, while the border on the distal side of the base is likewise straight and nearly parallel to the rachis. The nerves are slender, close, parallel, and but gently curved. None of the fragments in our collections show the very large terminal pinnules described and figured by Sir William Dawson as characteristic of the species. The general aspect and features of the species are well illustrated in Pl. III, Fig 1, prepared from one of the original specimens studied by Dawson, now in the collection of the Portland Society of Natural History. This example is typical of the dense arrangement of pinnæ and pinnules, commonly, though not invariably, found in this fern. The rachial pinnules, though not so well exhibited as in one of the fragments collected in 1903, are nevertheless indicated by several small fragments between the secondary pinnæ. The main rachis in this specimen is less rugose, transversely, than in other examples in

hand. In Pl. III, Fig. 2, is shown one of the typical fragments of a pinna collected in 1903, the details of the nervation, which suggests the Coxton Narrows specimens of *A. minor*, being given in Fig. 2ª.

The identity of the fructification of this species is still in doubt, but the specimen here figured (Pl. III, Fig. 4) can hardly be other than the same species as that from Scaumenac illustrated by Dawson[a] as *Archæopteris Jacksoni*. It is difficult to discern the position of the sporangia on the pinnules in this specimen, and so to ascertain whether or not they are pedicellate and fasciculate as described for this species by Dawson; but from my examination of the specimen I am disposed to believe that in the upper part of the pinna they may be in a single row along the midrib, which is prolonged in a narrow, upward curved semispinose process, after the fashion of many other species of the genus. This fragment I am, however, disposed to regard as perhaps but a young stage of the form shown in Pl. III, Fig. 5, which, although placed under *A. Rogersi* in deference to the judgment of Dawson, I suspect may belong, like other examples of *A. Rogersi* from Perry—the type locality—to *A. Jacksoni*. In his description of *A. Rogersi*, Dawson pointed out the more elongated, cuneate, and distal pinnules with more nearly parallel nerves, and the transversely rugose rachis as distinctive of the former as compared with *A. Jacksoni*. In leaflets of the latter, said to be the more common species at Perry, the nervation, as shown in Pl. III, Fig. 2ª, does not seem distinguishable from that given by Dawson[b] for *A. Rogersi*. As to the form of the pinnules, it is but poorly described and figured by Dawson; but the pronounced variation in width seen in different portions of the same frond in species of *Archæopteris*, as shown by Nathorst[c] in closely related species, or as may be seen in some of the fine slabs in the Lacoe collection of the United States National Museum, caution us against the specific separation of small fragments of the frond on account of the width of the pinnules. The same series of figures given by Nathorst and the same Lacoe specimens also illustrate the transverse rugosity of the rachis in some fragments, especially those nearer the base of the frond, while the more distal portions may be merely striated. In the example illustrated in Pl. III, Fig. 1, there is but faint indication of transverse corrugation in the rachis, but in some of the fertile examples, and in several of the fragments of larger rachis like that shown as *A. Rogersi*, Pl. II, Fig. 12, there is evident corrugation, though I have not seen any sterile pinnæ or pinnules which are not clearly *A. Jacksoni*, judging from the characters of the leaf form and the nervation.

The distinctions between *Archæopteris gaspiensis* and *A. Jacksoni*, for which Dawson at first mistook the former, are perhaps still less evident The former species

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[a] Fossil Plants of Erian and Upper Silurian Formations of Canada, pt. 2, pl. xxiv, fig. 17.
[b] Quart. Jour. Geol. Soc. London, vol. 19, pl. xix, fig. 27b.
[c] Oberdevonische Flora d. Bären-Insel, 1892, pl. v.

was originally described[a] as differing by the broader pinnules and the broader scaly or ramentose petioles, and especially by the arrangement and form of the sporangia, which are larger, more oblong, and are placed in pairs sessile on the midrib. It would seem also that the distinction between *A. Jacksoni* and *A. gaspiensis* is valid according to the characters of the fertile pinnæ, if we accept fertile fragments of the form of *Sphenopteris Hitchcocki* as representing *A. Jacksoni*. We are not yet in a position to determine the interrelations of *A. Jacksoni*, *A. Rogersi*, and *A. gaspiensis*.

It is interesting to note that none of the numerous fertile fragments which Dawson must have had from the same bed and place were referred by him to *A. Rogersi*, since he says the fertile pinnæ of the latter are unknown, though examples like that which I give under the latter species, Pl. III, Fig. 5, do not appear to be very rare. The specimens of the latter type are to be compared with the fertile pinnæ of *A. gaspiensis* figured by Dawson.[b] Incidentally it is perhaps significant, though merely circumstantial, that the fertile pinnæ at Perry which I thus tentatively place under *A. Rogersi* are possibly specifically indistinguishable from those of *A. gaspiensis*, which is described as distinguished chiefly by the absence of the transverse rugosity of the rachis, and as being otherwise difficult of separation, while *A. Rogersi* is recorded by Dawson[c] as associated with *A. gaspiensis* in the Gaspé region, just as it is with *A. Jacksoni* at Perry. I would add not only that some of the sterile pinnules of *A. Jacksoni*, in one of the larger specimens in the museum of the Portland Society of Natural History, have the form and size of *A. gaspiensis*, as figured by Dawson, but also that the specimens from Montrose, Pa., published by Lesquereux[d] as *A. Rogersi*, include fragments which, in my judgment, are hardly distinguishable from the sterile pinnæ of *A. Jacksoni* or *A. gaspiensis*. The fructification of the same fronds in the Montrose specimens seems to agree with that figured by me, Pl. III, Fig. 5, under *A. Rogersi*. It is hardly necessary to remark that the specific differentiation of the American species of *Archæopteris* is at present in a confused condition, which can not be satisfactorily resolved without a careful reexamination of the scattered types. For this reason, pending an opportunity to make such a special study of the American material, I leave the discrimination of the Perry species essentially as proposed by Dawson. The combination by Lesquereux of *Archæopteris Jacksoni* and *Sphenopteris Hitchcocki* with *Archæopteris laxa* (*Cyclopteris Halliana* (16pp.) appears to be unwarranted, the pinnæ of the latter being much more slender and flexuous, while the pinnules are delicate and less imbricated.

Archæopteris Jacksoni is present both in the shale bed on Little River and in the field near McPhail's.

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[a] Fossil Plants of Erian and Upper Silurian Formations of Canada, pt. 2, 1882, p. 99, pl. xxi, pl. xxiii, fig. 14.
[b] Loc. cit., pl. xxi, fig. 2. [c] Loc. cit., p. 100. [d] Coal flora, vol. 1, p. 307.

ARCHÆOPTERIS ROGERSI Dn.

Pl. II, Fig. 12, Pl. III, Fig. 5.

1863. *Cyclopteris Rogersi* Dawson, 2d Ann. Rept. Nat. Hist. and Geol. Me., 1862, p. 403.

1863. *Cyclopteris Rogersi* Dawson, Proc. Portland Soc. Nat. Hist., vol. i, pt. 2, p. 100, pl. ii, figs. 6, 7.

1863. *Cyclopteris Rogersi* Dawson, Quart. Jour. Geol. Soc. London, vol. xix, p. 463, pl. xvii, figs. 17, 18; pl. xix, figs. 27, 27a, 27b.

1871. *Cyclopteris* (*Archæopteris*) *Rogersi* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 46, pl. xvi, fig. 171, p. 85.

1863. *Cyclopteris Halliana* Göpp., Dawson, Quart. Jour. Geol. Soc. London, vol. xix, p. 462, pl. xix, figs. 28, 28a, 28b, doubtfully identified from Perry, Me.

1871. *Archæopteris Rogersi* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 48.

1879. *Archæopteris Rogersi* Dn., Lesquereux, Coal Flora, Atlas, p. 9, pl. lxix, figs. 9, 9a; text, vol. i (1880), p. 307.

1888. *Archæopteris Rogersi* Dawson, Geol. Hist. Pl., p. 279.

1886. *Palæopteris Rogersi* (Dn.) Kidston, Cat. Foss. Pl. Brit. Mus., p. 228.

Habit of growth resembling that of *Cyclopteris Jacksoni*, but with pinnules more elongated and almost cuneate in form and less densely placed, and with veins more nearly parallel; stipe stout, woody, furrowed longitudinally, and marked with strong transverse bars or punctures.

Not having seen any barren pinnæ in our collection from Perry except such as belong to *A. Jacksoni*, I have here quoted Dawson's diagnosis[a] of *Archæopteris Rogersi*, which was based on specimens from this locality, where it is said to be less common than *A. Jacksoni*. Its distinctive features, as compared to the latter, appear to be a stipe transversely corrugated and not leafy between the secondary pinnæ, and less densely placed pinnæ and pinnules, the latter being also generally narrower and more nearly cuneate.

The species is very inadequately illustrated for diagnostic purposes, and is therefore subject to some confusion, which can be resolved only by the examination of the type material. The two very small fragments of pinnæ figured by Dawson are so insufficient for the basis of a species that it is hoped that additional material from Dawson's hand in the original collections at Montreal may be found in support of the differentiation proposed by him. For reasons stated in my remarks on *Archæopteris Jacksoni* I am slightly inclined to regard *A. Rogersi* as representing narrow and more distantly arranged pinnules of the same species, such as are sometimes found in the upper part of large fronds of *Archæopteris*. This problem must, however, for the present remain unsettled.

The fragment of transversely corrugated rachis shown in Pl. II, Fig. 12, is one of a number of rachial fragments in our collections that are referable to *Archæopteris Rogersi*. In its superficial features it closely resembles the corresponding specimen figured by Gilkinet[b] as *Palæopteris Roemeriana*.

[a] Quart. Jour. Geol. Soc. London, vol. 19, 1863, p. 463.

[b] Bull. Acad. Roy. Belgique, vol. 39, 1875, p. 384.

In its corrugation the Perry rachis agrees well enough with Dawson's description of the original figure of a petiolar fragment, but in the traces of irregularly arranged scars to be observed in one or two examples our specimens strongly suggest fragments of the rachis of *A. gaspiensis*, described by Dawson as having indications of flat scales or ramentum. A similar specimen is in the collection of the Portland Society of Natural History. Since, however, the examination of several slabs of *Archæopteris* from the Devonian of Pennsylvania in the Lacoe collection of the United States National Museum or of the figures of *A. Roemeriana* given by Nathorst in his Devonian Flora of Bear Island shows the occurrence of both smoothly striate and transversely corrugated portions of rachis in the same fronds, I am disposed to regard this character as probably due more or less directly to circumstances of preservation and therefore of little specific value. It is not improbable that the corrugation itself is due to the presence in the cortex of horizontal sclerotic plates, which are expressed in the fossil according to the conditions of preservation, the cortical structure being presumably comparable to that described by Williamson and Scott in *Heterangium*.

Associated with the sterile pinnæ of *Archæopteris Jacksoni* I find several fragments of fertile pinnæ, which, since they do not conform to the characters given by Dawson for the latter species, I provisionally place in the other Perry species of *Archæopteris*, *A. Rogersi*, the fruit of which was unknown to the author of that species. As shown in Pl. III, Fig. 5, which represents an average specimen, the sporangia in this species are oblong linear, obtusely rounded, about 4–6 mm. broad and 2.5–3.5 mm. long, arranged singly or in pairs, with very short pedicels along the the midrib, which extends beyond the sporangia in a slender upward-turned prolongation. The sporangium itself is marked by a narrow longitudinal line, probably corresponding to the nerville. This character of the *Archæopteris* sporangium which has been illustrated by Dawson[a] is susceptible of interpretation as a rudimentary annulus. In one of our specimens the pinnæ and sporangia are smaller and more delicate, being intermediate to those placed by me (Pl. III, Fig. 4) under *A. Jacksoni*. The difference in size is perhaps due to immaturity, since the mode of arrangement on the midrib appears to be that shown in the larger specimens.

As already mentioned in my remarks on *Archæopteris Jacksoni*, it is possible, I believe, that this type of fertile pinna may belong to the last-named species. This supposition is to some extent supported by the relatively greater frequency of this form of fertile pinna in association with *A. Jacksoni* at Perry, by their close resemblance to the fertile pinnæ figured by Dawson[b] under *Archæopteris gaspiensis*, and by the occurrence of *A. Jacksoni* with *A. gaspiensis* in the Gaspé region. The

[a] Geol. Hist. Pl., 1888, p. 128, fig. 55a.

[b] Fossil Plants Erian and Upper Silurian Formations of Canada, pt. 2, pl. xxi, fig. 2.

very close relations of the Perry specimen to those from Montrose, Pa., described by Lesquereux[a] as *A. Rogersi* are to some extent corroborative of this view. The fertile specimens from Pennsylvania in the Lacoe collection are of the form here placed in *A. Rogersi*.

In his Devonian Flora of Bear Island, Nathorst[b] seems to regard *Archæopteris Rogersi* as probably referable to *A. Roemeriana* Goepp. It seems not improbable that the fragments from Perry, doubtfully identified by Dawson[c] as *Cyclopteris Halliana* Göppert, are but delicate specimens of *A. Rogersi*.

ARCHÆOPTERIS HITCHCOCKI (Dn.) D. W.

Pl. III, Figs. 6, 6ª, 6ᵇ.

1862. *Sphenopteris Hitchcocki* Dawson, Rept. Nat. Hist. and Geol. Me., p. 251, fig. 6.
1862. *Sphenopteris Hitchcocki* Dn., Hitchcock, Rept. Nat. Hist. and Geol. Me., p. 248.
1862. *Sphenopteris Hitchcocki* Dawson, Proc. Portland Soc. Nat. Hist., vol. i, pt. i, pp. 76, 77, pl. i, fig. 4.
1862. *Sphenopteris Hitchcockiana* Dawson, Quart. Jour. Geol. Soc. London, vol. xviii, p. 298.
1863. *Sphenopteris Hitchcockiana* Dawson, Am. Jour. Sci., 2d ser., vol. xxxv, p. 313.
1868. *Sphenopteris Hitchcockiana* Dawson, Acad. Geol., pp. 514, 518, 534, 552.
1871. *Sphenopteris Hitchcockiana* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 49, pl. xv, fig. 175; also p. 52.
1884. *Sphenopteris Hitchcockiana* Dn., Lesquereux, Coal Flora, vol. iii, p. 837.
1869. *Palæopteris Halliana* (Göpp.) Schimper, Traité. vol. i, p. 478 (syn.).
1895. *Cyclopteris Hitchcockiana* (Dn.) Solms-Laubach, Jahrb. d. K. preuss. geol. Landesanst., 1894, p. 86.

Main rachis large, very rugose, sometimes faintly corrugated transversely, and in fertile portions provided between the secondary pinnæ with very slender, narrow, deeply dissected or laciniate, oblique and recurved rachial pinnules, the dichotomous lobes or nerves of which bear sporangia at their apices; fertile secondary pinnæ, alternate, close, very oblique at the base and curving outward, the lower ones reflexed, tapering slightly, with moderately strong rugose rachises; lowest pinnules reduced to very narrow laciniæ, dichotomizing twice or more, the lobes fertile at the apex, the sporangia being broader than the laciniæ, more distal pinnules reduced to the usually once or twice dichotomous short midrib, and the lateral nervilles immediately forking once or more at a rather wide angle to furnish short pedicels for the sporangia; sporangia in lax or diffuse arrangement, often loosely fasciculate at the apices of the very short dichotomous nerves, 1.8–2.4 mm. long, oblong or slightly clavate, often slightly curved, the maximum width (0.5–0.6 mm.) being at the middle or a little below the obtuse or rounded apex, the base being narrowed and the dorsal surface traversed by a low narrow keel in continuation of the nerville.

The diagnosis given above is based on the counterpart of the original type from Perry, now in the geologic collection of the American Museum of Natural History,

[a] Coal Flora, vol. 1, p. 307. Nos. 16989, 16992, 16995, Lacoe Collection U. S. Nat. Mus.
[b] Oberdevonische Flora der Bären-Insel, 1902, p. 22.
[c] Quart. Jour. Geol. Soc. London, vol. 19, 1863, p. 462.

to whose courtesy, through Dr. E. O. Hovey, I am indebted for the opportunity for its reexamination and illustration. As shown in Pl. III, Fig. 6, the rachises of the lateral pinnæ are hardly in the plane of the surface of the shale, a condition not rare in fertile segments of *Archæopteris*.

A conspicuous and interesting feature of this type is the reduction of the rachial pinnules to narrow laciniæ, at the dichotomous apices of which sporangia are borne, as is shown in Fig. 6[a]. The lower pinnules of the secondary pinnæ are also unique in that they are reduced to narrow, several times dichotomous laciniæ, bearing sporangia at their apices. This feature is probably responsible for the original reference of the plant to the genus *Sphenopteris*. Higher in the secondary pinnæ the pinnules appear to be further reduced, so that a short midrib dichotomously gives off a few short nervilles, which usually fork once, or perhaps twice, immediately, to form the very short pedicels of the sporangia. It is to this spreading and dichotomously branched habit of the nerves or laciniæ that the plant owes its diffuse aspect.

The sporangia, often seen in foreshortened aspect in the matrix of this specimen, are (Pl. III, Fig. 6[b]) oblong, sometimes slightly enlarged upward, and generally very briefly pedicellate at the usually narrowed base. The residual substance of the sporangia is thick and carbonaceous, each sporangium being traversed by a narrow, low dorsal keel, which may correspond to a rudimentary ring.

The sporangia of this species are typical of the genus *Archæopteris*, a sterile fragment of which occurs on the same piece of shale. The correlation of *Archæopteris Hitchcocki* with any of the species known by their barren pinnæ is not yet definitely possible, on account of the lack of connection between the barren and fertile at Perry and the failure to discern the fertile species elsewhere in association with corresponding barren pinnæ. But it is not beyond the bounds of possibility that the specimen may represent a lower part of a fertile *A. Jacksoni*, whose fruit would appear to approach it by the position of the sporangia on the apices of forking veinlets.

The reference of *Sphenopteris Hitchcocki* to *Archæopteris* was first proposed essentially by Schimper,[a] who regarded it as the fertile pinnæ of *Palæopteris Halliana* (Goepp.) Schimp., to which he also provisionally referred *A. Jacksoni*. Dawson[b] seriously considered Schimper's views, though he remained unconvinced. Lesquereux, who in 1880[c] accepted Schimper's correlations, later restores[d] the species to *Sphenopteris*.

Schmalhausen[e] is disposed to interpret *Sphenopteris Hitchcocki* as a fruiting form closely related to his *Dimeripteris*. The latter genus, which will be discussed later, will at once be recognized as generically distinct. A striking example of the

[a] Traité paléont. vég., vol. 1, p. 478.
[b] Fossil Plants Devonian and Upper Silurian Formations of Canada, p. 52.
[c] Coal Flora, vol. 1, p. 304.
[d] Op. cit., vol. 3, 1884, p. 837.
[e] Mém. Com. Géol., vol. 8, No. 3, St. Petersburg, 1894, pp. 29, 30.

evils resulting from a too free interpretation of foreign imperfect descriptions and figures is furnished by Piedbœuf's inclusion[a] of *S. Hitchcocki* with *Haliserites Dechenianus*, *Fucus Nessigii*, *Psilophyton*, and *Sphenopteris condrusorum* in his *Sargassum Dechenianum*, supposed to belong to the *Fucaceæ*. By the form and characters of the sporangia and their position at the ends of forking veins *Archæopteris Hitchcocki* appears to be related to the fossil plant from the Devonian of Belgium described by Crépin[b] as *Psilophyton condrusorum*, the *Sphenopteris condrusorum* of Gilkinet.

OTIDOPHYTON D. W., gen. nov.

OTIDOPHYTON HYMENOPHYLLOIDES n. sp.

Pl. II, Fig. 3.

1863. An "Filicites incertæ sedis," Dawson, Quart. Jour. Geol. Soc., vol. xix, p. 464, pl. xvii, figs. 10, 16?

Fragments filicoid in form, with broad, lineate, rachial axis, bordered by rather thick and apparently somewhat fleshy, short, ovate lobes, which are open nearly at a right angle, laterally asymmetrical, slightly upward-pointed, and connate for about one-third of their length, the narrow, rounded sinuses being marked by small, roundish, dense, umbilicate organs about 0.5 mm. in diameter, and joined to the rachis by an oblique, decurrent, and rather thick strand; lamina of the lobes depressed along the rachis and nearly flat except near the slightly apiculate extremities of the lobes, where it appears to be marked, in most cases, at a distance of about 1.25 mm. from the border, by a small slightly depressed low mammilla.

The fragment here described is, like most of the other material from the Perry beds, more or less abraded or macerated, a fact which, in conjunction with the generally granular matrix, renders the interpretation of the impression and carbonaceous residue a matter of much difficulty; yet the salient features are sufficiently clear to make it identifiable for general paleontologic and stratigraphic use. It has therefore seemed desirable to give it a systematic nomenclatural designation, although the determination of the precise nature and functions of the parts are necessarily left to future discovery and research.

The habit of the pinna, Pl. II, Fig. 3, is strongly suggestive of a fern, with short, thick, fleshy lobes united at the base and separated in their distal portions by deep and narrowly rounded sinuses, at the base of each of which the thickened carbonaceous umbilicate impression, sometimes elongated radially and evidently joined by a thick outward curved strand to the rachis, is strongly suggestive of the synangium of *Hymenophyllum*. As will be seen by reference to Fig. 3, there is very good reason for believing that this sinal organ is sporophyllous. In the fragment illustrated it is constant in its occurrence between the lobes. In view of this interpretation it becomes, however, somewhat embarrassing to explain the small mammillate

[a] Mittheil. Naturf. Verein, Dusseldorf, 1887, pt. i, p. 47. [b] Bull. Acad. Roy. Belgique, vol. 38, 1874, pl. i, fig. 3.

depressions which occur within the apices of the lobes, and are likewise marked by a thickened carbonaceous residue. Other things being equal, these would naturally be taken for fructifications, but in this particular case such an interpretation is quite inadmissible, unless we conceive the plant to possess two distinct types of sporangia borne on the same pinna. It is possible that the one or the other is merely glandular, or that the sinal impressions are those of pedicellate organs or appendages. I am, however, slightly inclined to regard the peripheral traces as possibly glandular.

The specimen in hand does not satisfactorily reveal any definite system of nervation. Several of the lobes on the right hand of the axis appear to be somewhat distantly marked by depressed lines, lying generally parallel to the trend of the lobe and possibly bifurcating once or more, which bend downward near the rachis, but it is not possible to follow them with sufficient accuracy to establish their mode of origin or their precise habit of subdivision. They are probably to be regarded as the true nervation of the fleshy pinnules, although in other portions of the specimen no evidence of nervation is visible.

As compared with other Paleozoic plant types, the fragments in hand appear to resemble none sufficiently closely to indicate near relationship. As to the general aspect of the fragment, embracing a thick rachis bordered by dense fleshy lobes, the example shown in Fig. 3 is slightly suggestive of that from the lower Coal Measures of Missouri, described by the writer as *Brittsia*,[a] in which we have denticulately lobed pinnules or appendages arising from the sinuses between fleshy rachial lobes corresponding in general form and arrangement to that in *Otidophyton*. The latter, like *Brittsia*, also distinctly resembles the fronds described by Renault and Zeiller as *Zygopteris*.[b] This genus differs widely from the type in hand in the position of the sporangia.

From an examination of the figures of the unnamed fern from the Perry beds, published by Dawson[c] in 1863, it appears almost certain that the fragments described as having "dark spots, which are probably remains of fructification" in the sinuses, are referable to the genus, and perhaps to the species, described above, although the lobes are figured as narrower and the nervation is said to anastomose near the rachis.

The fragment illustrated is in general form and aspect somewhat similar to specimens described by authors as young examples of *Archæopteris*. Fig. 3 deserves especial comparison with the bipinnate example of almost exactly similar form from the Devonian of Condroz, illustrated by Crépin[d] as *Palæopteris hibernica*.

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[a] Mon. U. S. Geol. Survey, vol. 37, 1899, p. 98, pl. xlvii, figs. 1–5.
[b] Fl. foss. bassin houill. de Commentry, pt. 1, 1886, p. 77, pl. xxxii, figs. 5–7.
[c] Quart. Jour. Geol. Soc. London, vol. 19, p. 464, pl. xvii, figs. 10, 16.
[d] Bull. Acad. Roy. Belgique, vol. 38, 1874, p. 561, pl. iii, fig. 6.

BARRANDEINA Stur.

Sitzb. K. Akad. Wiss., Wien., math-nat. Cl., 1881, vol. lxxxiv, pt. i, p. 362.

BARRANDEINA PERRIANA (Dn.) D. W.

Pl. II, Fig. 11.

1862. *Anarthrocanna* sp., Dawson, Quart. Jour. Geol. Soc., vol. xviii, opp. p. 329.
1863. *Anarthrocanna Perriana* Dawson, Proc. Portland Soc. Nat. Hist., vol. i, pt. 2, p. 100, pl. ii, fig 3.
1863. *Anarthrocanna Perriana* Dawson, Second Rept. Nat. Hist. and Geol. Me., p. 403.
1863. *Anarthrocanna Perryana* Dawson, Quart. Jour. Geol. Soc., vol. xix, p. 461, pl. xvii, fig. 21.
1871. *Anarthrocanna Perryana* Dawson, Foss. Pl. Dev. Upp. Sil. Can., pp. 27, 85.

Rigid stems marked with broad, slightly irregular, low, flat, nearly contiguous, obscurely lineate ribs formed by the decurrent or appressed narrow bases of petioles or leaves, whose arrangement is spiral, the fracture being more or less oblique.

Under the name *Anarthrocanna perriana*, Dawson published a number of stem fragments of calamarian aspect, the leaf or petiole bases being described and figured as verticillate. From a number of small fragments in hand, one of which (Pl. II, Fig. 11) is illustrated herewith, it appears that the scars are arranged with more or less distinctness spirally instead of verticillately. The scars themselves are mere portions of very obliquely decurrent rachises or leaf bases whose succession in the longitudinal sense forms a slightly irregular low rib. Each leaf lower on the rib appears as if laid on the rib, with the width of which it coincides.

On account of the appressed condition and the mode of origin of the leaf bases the fractures are relatively lower, as regards the spiral, in some cases than in others; so it happens that in some instances they may appear to be verticillate. However, this aspect is, I believe, merely accidental. I am unable to recognize either the presence of nodes or of any enlargements corresponding to nodes such as are described by Dawson, whose figures, indeed, show no such enlargements. The reference of the Perry plant to Göppert's genus *Anarthrocanna* is untenable, since the latter genus includes exarticulate stems bearing verticillate branch scars.

The foliar characters and form of reproduction as well as the internal structure of the American plant are not known. The mode of decurrence of the leaf bases is somewhat similar to that seen in the secondary rachises of stems of *Archæopteris*. It is possible, on the other hand, that some of the supposed leaf fragments described as *Cordaites angustifolius* may have been borne on stems of this type, though it seems more probable that they will eventually prove to be fern stems. In this connection it is important to consult the fragment from the Hamilton of New York, figured by Dawson[a] as "*Cordaites?*", which would seem to be congeneric with the Perry plant. Both types, the New York type in particular, are so similar in their

[a] Quart. Jour. Geol. Soc. London, vol. 18, 1862, p. 318, pl. xvi, fig. 59.

rachial characters to the axis described by Krejči[a] as *Protolepidodendron Duslianum* and by Stur[b] made the type of *Barrandeina* as to require consideration as being generically identical. I have therefore tentatively placed the Maine plant in the genus *Barrandeina*. It should be compared with *B. Duslianum*, pl. v, figs. 3, 4, 5, of Stur's paper on the Flora of the H-h1 stage in Bohemia.

RHACHIOPTERIS Dawson.

Quart. Jour. Geol. Soc., vol. xviii, 1862, p. 323.

RHACHIOPTERIS PINNATA Dn.

1842. Plant ——, Vanuxem, Geol. 3rd Dist. New York, p. 191, fig. 57.
1889. Plant ——, Lesley, Dict. Foss. Pa., vol. ii, p. 657, text. fig.
1862. *Rhachiopteris pinnata* Dawson, Quart. Jour. Geol. Soc., vol. xviii, p. 323, pl. xvi, fig. 60.
1863. *Rhachiopteris pinnata* Dn., Hall, 16th Rept. Regents N. Y. St. Cab., p. 111, fig. 1.
1871. *Rhachiopteris pinnata* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 57.
1880. *Rhachiopteris pinnata* Dn., Lesquereux, Coal Flora, vol. i, p. 332.
1885. *Rhachiopteris pinnata* Dn., J. M. Clarke, Bull. U. S. Geol. Survey No. 16, pp. 28, 33.

RHACHIOPTERIS PINNATA Dn., VAR. ANGUSTIPINNA D. W.

Pl. IV, Figs. 1, 2, 3.

Bipinnate; axis rigid, irregularly and obscurely costate, irregularly lineate, slightly dilated laterally in passing upward to the bases of the secondary pinnæ; secondary pinnæ distichous, opposite about 4 to 5 cm. distant, at an angle of about 45° with the main rachis, rigid, narrow, of varying length, often seeming to terminate abruptly, strongly decurrent at the base, and conspicuously broadening the main rachis for some distance below the point of union; pinnules little known, very small, apparently somewhat distant, membranaceous, narrow, possibly oblong, irregular in outline, or lobate, not spread in the plane of the rachis.

Although little is known of the foliage of this type, the characters of the rachial portions are so nearly identical with those of the specimen from the Marcellus shale, middle Devonian of New York, made the type of the genus *Rhachiopteris* by Dawson,[c] that it seems not more than varietally separable from *Rhachiopteris pinnata* Dn. The chief distinctions recognized in the variety *angustipinna* lie in the less tapering secondary pinnæ, which are more slender at their bases, and in the absence of a distinct medial depression or pit on the surface of the main rachis between and nearly opposite each pair of lateral pinnæ, such as are shown in Dawson's illustration. Nevertheless, some slight depressions corresponding to those shown in *R. pinnata* are present, though not satisfactorily

[a] Sitzungsber. K. böhm. Gesell. Wiss., 1878 (1880), p. 333.
[b] Sitzungsber. K. Akad. Wiss., Wien., math.-nat. Cl., vol. 84, pt. 1, 1881, p. 362.
[c] Quart. Jour. Geol. Soc. London, vol. 18, 1862, p. 323, pl. xvi, fig. 60. The genus *Rhachiopteris* Dawson, 1862, must not be confounded with *Rhacopteris* Schimper, 1869, or *Rachiopteris* Williamson, 1874, the last being a homonym of Dawson's genus.

clear, in the Perry plant. It is possible that in this species the secondary pinnæ are in four vertical rows, tetrastichous, or that shorter pinnæ or pinnules at the ends of the abruptly terminated lateral rachises alternate with the pairs of secondary pinnæ.

The specimens present very little to indicate the characters of the pinnules borne by the rachises. On account of the coarse, irregularly fracturing nature of their matrix, their extremely delicate lamina, and the projected positions of their leaflets, only small fragments may be shown in definite relation to the rachis. A portion of such a pinnule is seen (Pl. IV, Fig. 3) on the second lateral pinna, which is not uncovered beyond. Its membranaceous lamina is ventrally broadly concave to the thread-like vascular axis. The examination of other specimens, such as that in Fig. 1, appears to show the presence of leaf bases or offshooting nerves at various points of the rachis, which becomes sparsely lineate toward the base. These lateral rachises are themselves marked by a somewhat loose or irregular denser median portion or narrow axis, which is sometimes in relief and sometimes depressed, and hardly exactly parallel with the margins. The latter suggest a thick wing. The aspect of these less dense lateral portions of the secondary rachises, in the presence of such apparently deficient transpiratory leaf surface, suggests that the bordering laminæ of the stem may have been stomatiferous.

An example of a larger secondary pinna, probably belonging to the same plant, is shown in Pl. IV, Fig. 3. Here we have remains of several pinnules still in evidence. I am disposed to interpret these pinnules as generally alternate and not more than 1.5–2.5 cm. distant on the same side. They are so delicate as to be abraded, shriveled, or curled at the borders in all or nearly all specimens I have found so far. In their general mode of division and form they strongly resemble the terminal, thin, recurving, laminar expansions which probably served as leaves in the smoother of the groups of plants referred by Dawson to *Psilophyton*. They represent, I believe, an early or rudimentary form of fern pinnule.

A very interesting phase of the lateral pinnæ is the apparently rapid if not almost abrupt termination of the rachis, either close to its base or at some distance from the main rachis. In some cases this is perhaps due to imperfect exposure of the specimens, though in others it would seem to be due either to rapid reduction of the axis attendant on foliar development or to fragility just above the leaf bases. The relative delicacy of the vascular axis, as compared with the rachises or lamina, illustrated in Pl. IV, Fig. 1, should be borne in mind in this connection. Similar specimens of secondary pinnæ with fragments of similar pinnules, found at a number of Devonian localities and almost certainly belonging to the same genus, have generally, though probably erroneously,

been referred to the genus *Ptilophyton*. In these fragments we similarly have a smooth, slender rachis with central thickened axis, often depressed or traversing a depression, and a more fleshy and evidently less fibrous wing on either side. So also these branches, and even the leaf bases themselves, often end abruptly in a blunt though not resistant recurved base, to which thread-like or delicate fragments of pinnules, or of the vascular axis of the distally macerated portion of the rachis, seems in some instances to adhere.

The fragments figured by Dawson, or seen in Pl. IV, Figs. 1 and 2, may with interest be compared with the portion of a fern skeleton from the Lenne beds (middle Devonian) of Oben zum Holz, figured[a] by Count Solms-Laubach, and compared with *Sphenopteris condrusorum*. In the Oben form we have opposite branches on the main rachis, which are evidently traversed by a distinct medial axis, while the strongly reflexed lobes of the divaricately forking ultimate divisions of the rachis are suggestive of the portion of a pinnule shown in Pl. IV, Fig. 1. In the regularity of the lateral pinnæ our plant suggests the species last mentioned, which was described by Gilkinet.[b] But while the rachial portions of the two ferns appear to have many points in common, the pinnules of the Belgian examples are distinctly sphenopteroid, more rigid, and regularly disposed, and are comparable to the *Sphenopteris moravicum* of Ettingshausen.[c]

Rhachiopteris pinnata also closely resembles defoliated fragments of *Archæopteris*, with opposite lateral pinnæ. It may, however, be distinguished from the latter by the broadened axis just above the axils of the pinnæ, which in *Archæopteris* are acute, the secondary rachises themselves being more rigid, fibrous, and without the bordering lamina.

Rhachiopteris punctata Dn. (?).

1842. Plant ——, Vanuxem, Geol. 3rd Dist. N. Y., p. 191, fig. 56.
1889. Plant ——, Lesley, Dict. Foss. Pa., vol. ii, p. 657, text-fig.
1862. *Rhachiopteris punctata* Dawson, Quart. Jour. Geol. Soc. London, vol. xviii, p. 323, pl. xvi, fig. 61.
1863. *Rhachiopteris punctata* Dawson, in Hall, 16th Rept. N. Y. State Mus. Nat. Hist., p. 113, fig. 4.
1871. *Rhachiopteris punctata* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 57.
1880. *Rhachiopteris punctata* Dn., Lesquereux, Coal Flora, vol. i, p. 332.
1884. *Rhachiopteris punctata* Dn., Williams, Bull. U. S. Geol. Survey No. 3, p. 14.
1888. *Rhachiopteris punctata* Dawson, Geol. Hist. Pl., p. 93.
1889. *Rhachiopteris punctata* Dn., Lesley, Dict. Foss. Pa., vol. ii, p. 657, fig. 56.

Fern stems, rigid, with somewhat coarse, irregular, longitudinal ribs, between which the impression is marked by small transverse ridges about 0.75 mm. distant, thus producing the appearance of vertical rows of very coarse punctuations between, and often lapping upon, the impressions of the large vascular bundles.

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[a] Jahrbuch K. preuss. geol. Landesanstalt u. Bergakademie, 1894, pl. ii, fig. 1, p. 93.
[b] Bull. Acad. Roy. Belgique (2), vol. 39, 1875, p. 393, figs. 1, 2.
[c] Fossile Flora Mahrisch.-Schles. Dachschiefers, p. 100, pl. iv, fig. 4.

The stems described by Dawson under the above name are, as was admitted by him, probably to be associated with *Archæopteris*. They perhaps represent specimens showing in a more marked phase the conditions of preservation often seen in rachises of the fronds of this genus. It is possible that the peculiar transverse fretting may be due to the presence of horizontal sclerotic plates in the cortex, comparable to those in *Heterangium*.

This species is perhaps of no value beyond indicating for its terrane the presence of some kind of *Archæopteris* whose petiole bases may be preserved so as to show a transversely rugose stem, a fact already recognized at Perry through the occurrence of *A. Rogersi*.

SPHENOPTERIDIUM Schimper.

Traité Pal. Vég., vol. iii, 1874, p. 487.

SPHENOPTERIDIUM sp.

Among the plants placed in my hands through the courtesy of Dr. R. T. Jackson, of the Museum of Comparative Zoology of Harvard University, I find a fragment of pinnule (No. 3,337) which by its form and nervation is very similar to some of the lobes of *Sphenopteridium furcillatum* found by Ludwig[a] and Potonié[b] in the collections from near Herborn, Hesse-Nassau. The terranes containing the latter are referred on nonpaleobotanical evidence to the Silurian; but the evidence of the plants themselves is sufficient to show that the *Sphenopteridium* beds are not older than upper Devonian.

DIMERIPTERIS Schmalhausen.

Mém. Com. Géol., vol. viii, No. 3, St. Petersb., 1894, p. 12.

DIMERIPTERIS INCERTA (Dn.) D. W.

Pl. II, Figs. 7, 8, 8ª, 9.

1862. *Cyclopteris incerta* Dawson, Quart. Jour. Geol. Soc. London, vol. xviii, p. 320, pl. xvi, fig. 44.
1871. *Cyclopteris incerta* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 65.
1884. *Cyclopteris incerta* Dn., Æsquereux, Coal Flora, vol. iii, p. 830.

Very slender stems occasionally forking more or less divaricately, with central axial strand, the lateral portions less dense and often irregularly costate or lax; lateral branches relatively short when fertile, becoming abruptly diffuse by rapid dichotomies at nearly a right angle, the ultimate divisions being very narrow, curved, or reflexed, extremely short; sporangia borne in clusters of 4 to 10 or more at the apices of the ultimate branchlets, sessile, imbricate in subglobular heads, oblong or oblong-lanceolate, about 2.5 mm. in length and about 0.6 mm. in diameter, obtuse and sometimes slightly flaccid; sterile pinnules not definitely known or correlated.

[a] Palaeontographica, vol. 17, No. 3, 1869, pl. xxiv.
[b] Abhandl. K. preuss. geol. Landesanstalt, n. s., vol. 36, 1901, pp. 20, 21.

The interesting fossils here described and illustrated furnish another example of the incompleteness of our knowledge of many of the older types of land plants. The stems of the form shown by several fragments in Pl. II, Figs. 7, 8, appear to be indistinguishable from others that have commonly been referred to *Psilophyton princeps*, which is recorded by Dawson as occurring at Perry. They are usually very slender, long, somewhat rigid, with central thickened vascular axes, which are often carinate in the impression. These stems or branch fragments often show short, abruptly terminated, branch, or leaf bases, to which adhere short, irregular filamentose remains, presumably branchlets or leaf nerves or fragments of pinnules. By their superficial characters they appear to be inseparable, at least generically, from specimens from Scaumenac labeled by Dawson as *Psilophyton princeps*. The agglomerations or heads of sporangia also appear to be directly comparable to those illustrated by Dawson[a] as *P. robustius*. The resemblance of the last-mentioned species touches also the characters of the rapidly and dichotomously diffuse fertile branchlets and the arrangement of the sporangia.

The specimens from Perry can not, however, be referred to the genus *Psilophyton*, as proposed by Dawson[b] in 1859, even if we allow for some uncertainty as to the true nature and characters of *Psilophyton princeps*,[c] the type of its genus. In the latter we have distinctly spinous or scaly stems, irregularly dichotomous and revolute, as shown by the figures, not circinnate? at the apex. The supposed fruit of the type is comparable in some respects to that from Perry. But from the descriptions and figures given by Dawson there would seem to be ample ground for questioning the congenerity of the species subsequently described as *P. robustius*, *P. elegans*, and *P. glabrum* with *P. princeps*. The more ample illustrations given by Dawson[c] in 1871 aid little in determining the problem, since we have both smooth and spinous stems under the type species of the genus, while the fruiting of the latter shown in his fig. 118 differs not only from that given in 1859, but also, in less degree, from that indicated in fig. 103 of the same work. As Count Solms-Laubach has pointed out,[d] the determination of the generic interrelations of the species described by Dawson as *Psilophyton* requires a thorough revision of the material with a reexamination of the types.

While doubt remains as to the generic identity of the Perry specimens with the type of the genus *Psilophyton*, whatever be their relations to *P. robustius* there is hardly room for question as to the precise congenerity of the plant in hand with the material made by Schmalhausen the type of his genus *Dimeripteris*.[e]

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[a] Fossil Plants Devonian and Upper Silurian Formations Canada, 1871, pl. xii.

[b] Quart. Jour. Geol. Soc. London, vol. 15, p. 478. Canadian Naturalist, vol. 5, No. 1, 1860, p. 2.

[c] Fossil Plants Devonian and Upper Silurian Formations Canada, pls. x, xi, xii.

[d] Jahrbuch K. preuss. Landesanstalt u. Bergakademie, 1895, pp. 73, 76.

[e] *Dimeripteris fasciculata*, Mém. Com. Géol., vol. 8, No. 3, St. Petersburg, 1894, pp. 12, 30, pl. i, figs. 10, 11.

The fragments in hand approach *D. fasciculata* so closely as at first to leave doubt as to the specific distinction between the Perry and the Donetz plants. The specimens shown in Pl. II, Fig. 7, should be compared with pl. i, fig. 11, of the Donetz-Becken flora. But the species is also still more closely bound to the specimen from the Hamilton of New York described and figured by Dawson[a] as *Cyclopteris incerta*. Although I should not have associated it with a rounded stem branching so freely as that illustrated by Dawson as belonging to the latter species, its sporangia are so similar both in arrangement and in form to those shown in fig. 44c of Dawson's plate that I tentatively place it in the same species. The subdivisions shown in 44b represent, I believe, ultimate branch divisions from which the sporangia have fallen. As such they should be compared with our Fig. 8. The curvature of the pedicels uniformly in the same direction in 44c is probably merely accidental. The apparent coalescence in the impression of the sporangia borne on two ramules in the upper part of this figure illustrates a feature common in our species, in which it is probable that in some cases the sporangia of more than one ramule are blended in the branch or head. Dawson's figure fails to show the features of the individual sporangium, and I am not certain whether they agree in all respects with those revealed in the coarse matrix at Perry.

The type of fructification here described seems to have close analogies in other plants described from the Devonian of various regions. In the aspect of the heads, the development of the sporangia from rapidly dichotomizing ramules, and the characters of their sporangia themselves, *Dimeripteris incerta* and *D. fasciculata* are to be compared with the fructification from the Devonian of Bear Island described by Nathorst[b] as *Cephalotheca mirabilis*. Were it not that the sporangial heads in the latter are almost sessile in the proximal angles at the bases of the secondary pinnæ the plants would of necessity be regarded as very closely related species of the same genus. The fructification of the plant in hand also resembles in some respects that described by Vaffier[c] as *Alcicornopteris Zeilleri*, from the lower Culm of Maconnais, or the *Calymmotheca bifida* figured by Kidston[d] from the Calciferous sandstone series of Scotland. However, the plant in hand is very readily distinguished from both of the latter types by the great differences in its rachial development and mode of division.

Several fragments of irregularly lobed, delicate ramules (or pinnules?) in the collection may represent the leaves of *Dimeripteris incerta*. They are, in general, membranaceous laminæ traversed by slender central nerve strands, and are com-

[a] Quart. Jour. Geol. Soc. London, vol. 18, p. 320, pl. xvi, fig. 44.
[b] Kongl. svensk. Vet.-Akad. Handl., vol. 36, No. 3, 1902, p. 18, pl. 1, figs. 18–35.
[c] Annales Univ. Lyon, n. s., vol. 1, fasc. 7, 1903, p. 124, pl. vii.
[d] Trans. Royal Soc. Edinburgh, vol. 33, pt. 1, 1887, pl. viii, figs. 1–6.

parable to those described as *Rhachiopteris pinnata* var. *angustipinna*. They also resemble some of the slender, nonpunctate stems erroneously placed in *Psilophyton princeps*. The phases and characters of certain of the ramose stems at Perry will be described more particularly in connection with the supposed Psilophyta from the same place.

None of the sporangia provisionally referred to *Dimeripteris incerta* show the mode of dehiscence. There is, therefore, doubt as to whether the bivalvate or bilobate organs later to be compared with *D. gracilis* represent the generic type of sporangia described above. The coincidental association of the forms described by Schmalhausen as *Dimeripteris fasciculata* and *D. gracilis* in the Donetz beds; the *D. incerta* and fossils of the type shown in fig. 103 of Dawson's plate in the American Devonian; and the similar association of the fasciculate with the bivalvate bodies next to be described at Perry are interesting analogous conditions, if they do not bespeak direct relationship.

DIMERIPTERIS RECURVA (Dn.) D. W.

Pl. II, Figs. 4–6.

1862. *Sphenopteris* sp., Dawson, Quart. Jour. Geol. Soc. London, vol. xviii, opp. p. 329.
1863. *Sphenopteris* sp., Dawson, Proc. Portland Soc. Nat. Hist., vol. i, pt. 2, p. 100, pl. ii, figs. 8, 8a.
1863. *Sphenopteris* sp., Dawson, 2d Rept. Nat. Hist. and Geol. Me., p. 104.
1863. *Sphenopteris recurva* Dawson, Quart. Jour. Geol. Soc. London, vol. xix, p. 464, pl. xvii, figs. 7, 8.
1871. *Sphenopteris recurva* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 53.

'Pinnules at the summits of slender-curved or geniculate, closely dichotomous ramules, very small, cuneate or obovate-cuneate, slightly curved upward, very obtuse, dichotomously bilobate, with thin narrowly decurrent lamina; sporangia narrowly obovate, paired or clustered, a little smaller than the lobes of the pinnules, apparently bivalvate.

Among the material collected in 1903 are a number of very small specimens which appear to represent the *Sphenopteris recurva* of Dawson. Pl. II, Fig. 5, shows the common form of the pinnular fragments, and illustrates well the dichotomous division of the pinnules which have in some instances the aspect of empty sporangia. A fragment possibly representing sporangia, and without doubt referable to the same species, is drawn in Pl. II, Fig. 6. I have no clear proof that the sporangia are bivalvate. In Pl. II, Fig. 4, is shown a fragment of a pinna which I believe belongs to *Dimeripteris recurva*.

The reference of these specimens to *Dimeripteris* is based on the apparently close relation of the material in hand to that described by Schmalhausen[a] as *Dimeripteris gracilis*. There seems to be little doubt that they are congeneric, but the reason why *Dimeripteris gracilis*, which I am inclined to think may be identical

[a] Mém. Com. Géol., vol. 8, No. 3, St. Petersburg, 1894, p. 30, pl. ii, figs. 23–25.

with its associate, *Sphenopteris Lebedevi* Schm., is included in the same genus as *D. fasciculata* does not appear to be entirely clear.

Specimens like that in Pl. II, Fig. 6, may be compared with those given by Dawson on pl. ix, fig. 103, of his Devonian and Upper Silurian Flora[a] as sporangia of *Psilophyton princeps*. The latter are also described as bivalvate. I have not been able to associate the fossils here figured with any particular type of stem or rachis and therefore can not say if they are peculiar to the stems from Perry which have been doubtfully identified as *Psilophyton princeps*. The specifically distinct fragment shown under the latter name in pl. x, fig. 118, of Dawson's memoir also deserves comparison with *Dimeripteris gracilis*. The interesting coincidence in finding at Perry two plants apparently corresponding to *Dimeripteris fasciculata* and *D. gracilis* of the Donetz locality has already been noted in my remarks on *D. incerta*. In the development of the pinnules the plant in hand is comparable to *Sphenopteris flexilis* Heer,[b] from the lower Carboniferous of Spitzbergen, while the bivalvate aspect of the large lobes suggests the fragment figured without name by Unger[c] from the Cypridina beds of Thuringia.

SPHENOPTERIS Sternberg.

Vers. Fl. Vorwelt, vol. 1, Tent., 1825, p. xv.

SPHENOPTERIS FILICULA (Dn.) D. W.

1862. *Trichomanites* sp., Dawson, Quart. Jour. Geol. Soc. London, vol. xviii, opp. p. 329.
1863. *Trichomanites* sp., Dawson, Proc. Portland Soc. Nat. Hist., vol. i, pt. 2, p. 100, pl. iv, fig. 9.
1863. *Trichomanites* sp., Dawson, Second Rept. Nat. Hist. and Geol. Me., p. 404.
1871. *Trichomanites* sp., Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 86.
1863. *Trichomanites filicula* Dawson, Quart. Jour. Geol. Soc. London, vol. xix, p. 464, pl. xvii, figs. 12, 13.
1871. *Trichomanites filicula* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 56.

Cuneate to broadly ovate pinnules dichotomously dissected, generally at a narrow angle, in skeleton form, the lobes rigid, linear, obtuse, but little wider than the nerves, which are slightly depressed ventrally and very narrowly alate.

Little can be said of this species, which has been recognized in a few small fragments only. Our specimens show a more oblique subdivision of the pinnules, with greater regularity and rigidity in the lobation, and with rather broader lobes, than is shown in the two small figures published by Dawson.

The plant here described agrees so closely with that from the upper Devonian of Bear Island, illustrated as *Sphenopteridium* by Nathorst in the first plate (figs. 16, 17) of the Paläozoische Flora der Arktischen Zone,[d] as to raise the question

[a] Fossil Plants Devonian and Upper Silurian Formations Canada, 1871.
[b] Flora Fossilis Arctica, vol. 4, No. 1, Pl. I, figs. 11-27.
[c] Richter and Unger, Denkschr. K. Akad. Wiss., Wien, math.-nat. Cl., vol. 11, 1856, pt. 2, p. 99, pl. vii, fig. 25.
[d] Kongl. svensk. Vet.-Akad. Handl., vol. 36, No. 3, 1902, p. 14.

whether it is not specifically identical with the latter. It is also comparable to the *Sporochnus Krejči* of Stur,[a] from the upper Devonian (H–h1) of Bohemia. From the characters of the portions of pinnules before me the species appears also to be related to the *Sphenopteris flaccida* described by Crepin,[b] from the Devonian of Condroz and the *S. vespertina* of the American Pocono. I find no evidence in support of a relationship of the plant to *Aphlebia*, as was suggested by Dawson.

PSILOPHYTON Dawson.

Quart. Jour. Geol. Soc., vol. xv, 1859, p. 478.

? PSILOPHYTON CF. PRINCEPS Dn.

Pl. V, Figs. 3–7; Pl. VI, Figs. 7, 8.

1859. *Psilophyton princeps* Dawson, Quart. Jour. Geol. Soc. London, vol. xv, pp. 478, 479, 480, figs. 1a–1m.
1860. *Psilophyton princeps* Dawson, Can. Nat., vol. v, No. 1, Feb., p. 34, figs. 1a–f.
1861. *Psilophyton princeps* Dawson, Can. Nat., vol. vi, No. 3, June, p. 175.
1862. *Psilophyton princeps* Dn., Hitchcock, Rept. Nat. Hist. and Geol. Me., 1861, p. 248.
1862. *Psilophyton princeps* Dawson in Hitchcock, Proc. Portland Soc. Nat. Hist., vol. i, pt. 1, p. 76.
1862. *Psilophyton princeps* Dawson, Quart. Jour. Geol. Soc. London, vol. xviii, p. 298.
1863. *Psilophyton princeps* Dawson, Am. Jour. Sci. (2), vol. xxxv, p. 313.
1863. *Psilophyton princeps* Dawson, 2d Rept. Nat. Hist. and Geol. Me., p. 402.
1863. *Psilophyton princeps* Dawson, Quart. Jour. Geol. Soc. London, vol. xix, p. 462.
1868. *Psilophyton princeps* Dawson, Acadian Geol., p. 543.
1870. *Psilophyton princeps* Dawson, Nature, vol. ii, p. 86, figs. 1, 1a–1c.
1871. *Psilophyton princeps* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 37, pl. ix, x, figs. 111–119; pl. xi, figs. 127–129, 133, 134.
1882. *Psilophyton princeps* Dawson, Chain of Life, p. 95, figs. 87a–c.
1888. *Psilophyton princeps* Dawson, Geol. Hist. Pl., p. 64, figs. 19a–c.
1887. *Psilophyton princeps* Dawson, Geol. N. S. and N. B., p. 543, Supplement, p. 71, fig. 12.

Stems not very robust, irregularly and more or less unequally dichotomous, subgeniculate to straight, usually gently curved between the branches, dilated at the points of division, 2–6 costate when flattened, the costæ rounded and separated by several slightly uneven furrows equaling the costæ in dimensions; branches very open, marked in impressions by an oval depression a few millimeters above the point of origin, fewer costate than the axis, and dividing pinnately to dichotomously or dividing almost abruptly to dichotomous, lax, thin, narrow, recurved foliar organs not in the same plane.

The provisional reference, with expressed doubt, of the above-described fragments to the genus *Psilophyton* is based (1) on their generic if not specific agreement with material from New York and Canada referred by Dawson and other paleontologists to *Psilophyton princeps*, (2) on the record by Dawson of

[a] Sitzungsber. K. Akad. Wiss., Wien, math.-nat. Cl., vol. 84, pt. 1, 1881, pl. ii, figs. 1, 2.
[b] Bull. Acad. Roy. Belgique, vol. 38, 1874, p. 360, pl. i, fig. 3.

the latter species at Perry, and (3) on the examination of specimens from Perry, labeled with the latter name by Sir William Dawson himself, in two collections which have been placed in my hands. Yet I have been strongly of the opinion that none of this material is specifically identical with the plant originally described[a] from Gaspé as *Psilophyton princeps*, and am even doubtful whether the two are congeneric.

The relation of the stem fragments from Perry to the typical *Psilophyton* of Dawson can best be discussed after the description of the former.

The general features so far as exhibited in the material in hand may be readily understood by an examination of the figures of a number of the fragments. In Pl. V, Fig. 3, is shown a not entirely flattened rachis in which the branches, as usual either broken or abruptly terminated, are given off alternately. In its flexuosity and ramification this example is comparable to specimens from Campbellton labeled as *Psilophyton princeps*, though it is not so clearly costate as the latter. In general form this fragment is also remarkably like some of the fragments in the New York State collection labeled by Dawson as *Rhachiopteris tenuistriata*. A possible confusion of *Psilophyton* and *Rhachiopteris* in some species was long ago suggested[b] by the author of both genera.

A fragment with more rigid rachis, shown in Pl. V, Fig. 4, well illustrates the abrupt form of termination of the lateral branchlets, which is so common and characteristic in fossil stems of this type. It also shows the depression or elongated pit in the basal portion of each branchlet. A peculiar character is the rapid fading out or practical vanishment of the branchlets. This is perhaps often due in some of the smaller branchlets to the diminution of rigidity and the almost abrupt transition to the thin, lax, bifurcating lamina, presumably of foliar function, which has been destroyed by erosion. In many cases, however, the seemingly abrupt ending is due in part to rapid ramifications as well as increasing tenuity, the ramification, like the foliation, being not in the plane of the impression, and being usually covered or abraded. This specimen serves to illustrate the costation of the rachis and the decurrence of the rameal strands.

In Pl. V, Fig. 5, is shown a rachial fragment of a more slender form which appears to agree with similar fragments recorded as belonging to the above-named species. The ramules are evidently foliate, though largely removed by erosion. Fragments of the lax laminate expansions of the branches, which I interpret as foliar, are shown in Pl. VI, Fig. 8. The aspect of the divisions is comparable to that originally shown by Dawson[c] in *Psilophyton grandis*. The abrasion to which the Perry sediments have been subjected has generally destroyed the more delicate

[a] Quart. Jour. Geol. Soc. London, vol. 15, 1859, pp. 478–480; Canadian Naturalist, vol. 5, 1860, No. 1, p. 2.
[b] Fossil Plants Devonian and Upper Silurian Formations Canada, 1871, p. 57.
[c] Quart. Jour. Geol. Soc. London, vol. 15, 1859, p. 481, figs. 2a, 2b.

portions of the plants, but the comparison of many of the imperfect fragments with other material from the Devonian of New York shows them to be generically identical.

In order better to illustrate both the branching and the foliar termination in the smoother type of *Psilophyton* I show (Pl. V, Fig. 7) a part of a specimen from Campbellton, New Brunswick, now in the United States National Museum collection, choosing it because it was identified by Dawson as *Psilophyton princeps*. In this example we see no distinct traces of spines or scale-leaves, though traces of obscure and distant punctation (exaggerated in the figure) are rarely observed in small portions of the fragments. The costæ, which are well displayed, are slightly irregular and the furrows are of varying depth. The fragments of divaricately recurved lamina, which terminate the rachises, and which I interpret as possessing leaf functions, are in general typical of a plant form common in the Devonian and are usually regarded as characteristic of *Psilophyton*, though they do not seem to be clear in the original Gaspé figures.

A laminar development similar to that shown in our figure is also found in both the rachial and terminal portions of the specimens illustrated by Stur[a] as *Hostinella hostinensis*. The terminal fragments shown in Stur's pl. iv, fig. 5, of the flora of etage H-h1 are so nearly of the type seen in Campbellton specimens as to leave scarcely room for doubt as to the generic identity of the types. A closely similar mode of division and rachial termination is seen also in the branches shown in fig. 3, pl. vii, of Miller's Old Red Sandstone and referred by Dawson to *Psilophyton*, and in the frond from the Lenne beds cautiously described by Solms-Laubach[b] as a fern skeleton.

Pl. V, Fig. 6, and Pl. VI, Fig. 7, illustrate two small rachial fragments from Perry, which show the peculiar branching in equal dichotomy sometimes seen in these plants. Occasionally the division appears to be unequally trifurcate and, like the example, Pl. VI. Fig. 7, not in the plane of the rachis.

Passing now to the question of the generic identity of the plants in hand, I have to state that none of the specimens in our collections from Campbellton or from New York, to which I have referred, exhibit the distinct spines or spiny scales ("leaves") on stems or branches, the closely revolute ("circinnate vernation") development of the branches, the pitted rhizomes, or the rachial scale-scars described and illustrated in Dawson's original publication of the genus and species. The Campbellton examples are practically smooth. In fact, with the exceptions of examples from Gaspé, the material described by Penhallow[c] as *Psilophyton grandis*, and some specimens from the Hamilton at Mapleton, Aroostook County, Me., I have seen no

[a] Silur-Flora der Etage H-h1: Sitzungsber. K. Akad. Wiss., Wien, math.-nat. Cl., vol. 84, pt. 1, 1881, pl. iv.
[b] Jahrb. K. Preuss. Geol. Landesanstalt, 1894 (1895), pl. ii.
[c] Proc. U. S. Nat. Mus., vol. 16, 1893, p. 113, pl. xii, fig. 12a; pls. xiii, xiv.

specimens in our collections which may without question be referred to *Psilophyton* as the genus seems to have been originally founded by Dawson in 1859.

The confusion as to *Psilophyton* dates back to the supplementary descriptions and figures given by Dawson[a] in 1871, where we find both spiny and smooth stems placed in *Psilophyton princeps* together with two other types of fructification,[b] neither of which appears to be reconcilable with that originally shown in 1859 and 1860.

In order to aid me in gaining a clearer view of the genus, Professor Penhallow, of McGill University, Montreal, has been so courteous as to place in my hands for comparison typical and excellent material from Gaspé and Campbellton, labeled *Psilophyton princeps* by Dawson.

From the examination of these specimens I am convinced that the variety *ornatum* is not specifically identical with the Campbellton smooth type; but since the material submitted does not, unfortunately, include the types of the species and genus, there is still some doubt as to the precise characters of the Gaspé originals. There is, however, I believe, little doubt that the so-called variety *ornatum* represents the original type species of the genus, its varietal discrimination being of doubtful validity. The specimens from Gaspé belonging to this, the spinous plant, are readily distinguishable from those of the few-costate, smooth, and more ramose plant, and clearly show the spines or spine scars, even in the inrolled, somewhat blunt, apical portions. The latter, as shown by No. 3239 of the McGill University collection, are truly inrolled and circinnate instead of revolute, since one of the fragments displays lateral pinnæ also in circinnate vernation just below the apical coil. The aspect of the specimen is filicoid.

The characters of the larger stem fragments of the true *Psilophyton* from Gaspé are well shown in pl. ix of the Flora of the Devonian and Upper Silurian Formations (1871), the spines being not exaggerated either as to length or rigidity in figs. 104 or 110. Those on the smaller divisions of the rachis, such as are shown in Dawson's fig. 100, appear to correspond to the type figures published in 1859 and 1860. Occasionally in the stem impressions the spines are marked by distinct and sometimes distant pits. The fragments of fertile pinnæ from Gaspé lent me by Professor Penhallow, though obscure, seem to correspond to Dawson's fig. 102; and are distinctly punctate and thus referable to the typical species.

The relatively smooth or Campbellton type of plant, referred, erroneously, I believe, by Dawson to *Psilophyton princeps*, is represented in Pl. V, Fig. 7. Its characteristic costation is nearly always in evidence, there being no indication of spines except that furnished by a minute and very distant and obscure punctation, which is difficult to observe in most cases. It is also more lax, branching very freely,

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[a] Fossil Plants Devonian and Upper Silurian of Canada, p. 37, pls. ix, x, figs. 111–119; pl. xi, figs. 127–129, 133, 134.
[b] Loc. cit., pp. 37, 89, pl. ix, figs. 102, 108; pl. x, fig. 118.

especially near the apex, which is very delicate (Pl. V, Fig. 7*a*) as well as intricate on account of the frequent divaricate dichotomies. In the specimens of the typical species from Gaspé I have seen none of these divaricate terminal laminar developments which form so constant a feature of the smooth Campbellton plant, and I am consequently inclined to regard this development as somewhat characteristic of a particular group to which the Campbellton plant belongs.

Whether the smooth costate (Campbellton) type is congeneric with the true type of *Psilophyton princeps* (=var. *ornatum*) must be demonstrated by further study and by examination of the types. The former probably represents the genus *Hostinella* of Stur. It is possible that a generic connecting link between them may be found in *Psilophyton robustius*, the rachis of which is punctate though its axis is filicoid. There would appear, however, to be some reasons for regarding the latter as a generically distinct form. It is doubtful whether punctation of the rachis, which may represent an environmental effect, is to be regarded as of generic diagnostic value in such cases. A stronger argument appears to obtain in the similarity in the fructification as described and figured.

To the true *princeps* group, as illustrated in Dawson's original figures and in the spiny stems published in 1871, belongs, as congeneric, the *Psilophyton grandis* of Penhallow from the Genesee of New York, the habit of the stems as well as their mode of division being identical. To the same group should probably also be referred the specimens from the "Old Red Sandstone" of northern Scotland, described by Carruthers[a] as *Haliserites Dechenianus*, though they differ by their closer spines from *Psilophyton princeps*. Specimens of *P. princeps* lent by Professor Penhallow are densely carbonaceous, and seemingly vascular, as, indeed, the type is described to be by Dawson. Yet the comparison is very greatly to be desired of the structure of suitably preserved typical fragments with that of *Prototaxites*, the carbonaceous residue of which might also be dense and of fibrous superficial aspect.

The specimens illustrated by Göppert[b] as *Haliserites Dechenianus* can be referred to *Psilophyton* only on the assumption that they are very erroneously figured. As apparently true Psilophyta, mention should also be made of the stems figured by Salter[c] as *Lycopodites Milleri*, and by Crépin[d] as "*Lepidodendron gaspianum* Dn. ?", from the Devonian of Rouveroy. The union of *Lepidodendron gaspianum* with *Psilophyton*, proposed by some botanists, is wholly unwarranted.

The larger stems of the true *Psilophyton* (var. *ornatum*) from Gaspé are so rugged, bear such long, radiating spines, and approach in aspect so closely to the

[a] Jour. Bot., November, 1875, pl. cxxxvii.
[b] Fossile Flora des Uebergangsgebirge, 1852, p. 88, pl. ii.
[c] Quart. Jour. Geol. Soc. London, vol. 14, 1858, pl. v, p. 75.
[d] Bull. Soc. Roy. Bot. Belgique, vol. 14, 1875, pls. iv, v.

figures of Dawson's *Arthrostigma gracile* as to suggest that they are but the smaller branches of the latter.[a] However, it must be remembered that, notwithstanding the apparently irregular distribution of the spines in the figures, they are described as verticillate, a character which, if valid, precludes any serious comparison with *Psilophyton* or with Göppert's *Drepanophycus spinæformis*,[b] which after all may prove to be generically identical with the type species of *Psilophyton*. For the costate nonspinous type of stems the name *Hostinella* proposed by Stur may be found applicable should their apparent generic distinction be confirmed by the examination of Dawson's originals. The rachises in the Devonian material of what we may provisionally term the *Hostinella* type in Canada and in Maine are less rigid than those of *Aneimites* and *Adiantites* from the lower Carboniferous and lack the strict angularity of the branches of the latter genera at the points of division.

The curved branching stems from Maine should be compared with the fragments from the Devonian of Spitzbergen described by Nathorst in the first part of the Palæozoischen Flora der Arktischen Zone.[c] Also our Pl. V, Figs. 4 and 6, show precisely the characters seen in the stem fragments illustrated in the second part of the work,[d] which described the Devonian flora of Bear Island. The close similarity in features between the original of our Pl. V, Fig. 6, and the examples shown by Nathorst in pl. i, figs. 24–33, of the latter memoir is especially significant in view of the almost equally close agreement between the sporangial heads, *Cephalotheca mirabilis* Nath., attributed to these stems in the Bear Island Devonian, and the fructification from Perry which I have described (Pl. II, Figs. 7–9) as *Dimeripteris incerta*.

The examination of such so-called *Psilophyton* material as I have seen shows the existence in America of two or more groups, represented by several fairly well-marked species which possess stratigraphic value, and which should be carefully diagnosed and illustrated. It is probable also that additional material throwing light on the structure and relationships of these very remarkable early types of land plants will be discovered at some locality. The inspection of the material in hand emphasizes the need, as was pointed out by Solms-Laubach,[e] for the revision of the material referred by various authors to *Psilophyton*, together with a thorough reexamination and republication of the types.

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[a] Fossil Plants Devonian and Upper Silurian of Canada, 1871, p. 41, pl. xiii.
[b] Fossile Flora des Uebergangsgebirge, 1852, p. 92, pl. xli, fig. 1.
[c] Kongl. Svensk. Vet.-Akad. Handl., vol. 26, No. 4, 1894, pl. i.
[d] Op. cit., vol. 36, No. 3, 1902.
[e] Jahrb. K. pr. geol. Landesanstalt, 1894 (1895), p. 76.

PSILOPHYTON? ALCICORNE D. W.

Pl. V, Figs. 1, 2.

Axis (rhizome?) flexuose, irregularly lineate, branching from one side at right angles at intervals of a few centimeters, the branches greatly dilated at their bases along the axis in a more or less trapezoidal expansion, with rounded sinuses above and below, and immediately emitting an ascending ramule, while the recurving branch at once forks again at a very wide angle to furnish a second ramule close to and nearly parallel to the first; branchlets relatively wide, rather dense, and traversed by a central strand, which sometimes appears in the impressions.

The aspect and general characters of this type of fossil are represented in the figures of two specimens, Pl. V, Figs. 1, 2. It will be seen that in the latter specimen the peculiar system of branching is further carried out. At the apex of the fragment represented in Fig. 1 was a branch similar to those shown lower in the specimen, but this was accidentally destroyed in removing the matrix.

The specimens here described are suggestive of rhizomes from which fronds arise, though they also suggest some algal forms. I tentatively refer them to the genus *Psilophyton*, on account of the similarity in their method of branching to that sometimes seen in stems of that genus. This similarity, as illustrated in a National Museum specimen from the Devonian at Campbellton (Pl. V, Fig. 7), is marred by the degree of complication only, the main branch being less strongly recurved and not forked again immediately. A minor reason for not treating the plant as representative of a new generic type is the occurrence, in the same bed, of fragments agreeing with the plants generally identified as *Psilophyton*. Our example is, however, totally distinct from the rhizome described by Dawson as belonging to the latter genus. Nevertheless, in spite of the difference in general ramification, I am not at present disposed to regard the fossils as representing a new genus.

The species is well marked and easily recognized by the characters of the unique mode of branching, which, so far as observed, is confined to one side of the axis, thus imparting a rhizomal aspect.

PALÆOSTACHYA Weiss.

Steinkohlen-Calamariæ, pt. 1, 1876, p. 103.

PALÆOSTACHYA ? sp.

Pl. IV, Fig. 4.

The collection of 1903 contains a single small fragment (Pl. IV, Fig. 4) of an axis bearing strong, basally open, or slightly reflexed bracts of lepidophytic aspect, each bearing, at a point just above its base, a slightly oblique sporangiophore sup-

porting two (or four?) short oblong sporangia. The position of the sporangiophore and sporangia appears to justify a tentative and provisional reference of the plant to *Palæostachya*. But it must be noted that the bracts are very thick and decurrently attached at the base, and, especially, that there are no traces either of nodes in the stem, the full width of which is not seen, or of a verticillate arrangement of the scales. Fragments of the kind here illustrated might, if the sporangia were detached, readily be mistaken for *Lepidodendron* or *Lycopodites*, and bear, in fact, a strong resemblance in profile to *Lepidodendron gaspianum*.

BARINOPHYTON D. W., gen. nov.

BARINOPHYTON RICHARDSONI (Dn.) D. W.

Pl. IV., Figs. 5, 5ª, 6, 7, 8.

1861. *Lepidostrobus* sp., Dawson, Can. Nat., vol. vi, no. 3, June, p. 174.
1862. *Lepidostrobus* sp., Dawson, in Hitchcock, Proc. Portland Soc. Nat. Hist., vol. i, pt. 1, p. 76.
1861. *Lepidostrobus Richardsoni* Dawson, Can. Nat., vol. vi, no. 3, June, p. 174.
1862. *Lepidostrobus Richardsoni* Dawson, in Hitchcock, Geol. Me., 1861, p. 248, figs. 10, 10a.
1862. *Lepidostrobus Richardsoni* Dawson, Proc. Portland Soc. Nat. Hist., vol. i, pt. 1, p. 76.
1862. *Lepidostrobus Richardsoni* Dawson, Quart. Jour. Geol. Soc. London, vol. xviii, p. 298.
1863. *Lepidostrobus Richardsoni* Dawson, Am. Jour. Sci., 2d ser., vol. xxxv, p. 313.
1863. *Lepidostrobus Richardsoni* Dawson, Proc. Portland Soc. Nat. Hist., vol. i, pt. 2, p. 100.
1863. *Lepidostrobus Richardsoni* Dawson, Second Rept. Nat. Hist. and Geol. Me., p. 403.
1862. *Lycopodites Richardsoni* Dawson, Quart. Jour. Geol. Soc. London, vol. xviii, leaf opposite p. 329.
1863. *Lycopodites Richardsoni* Dawson, Second Rept. Nat. Hist. and Geol. Me., p. 403.
1863. *Lycopodites Richarasoni* Dawson, Quart. Jour. Geol. Soc. London, vol. xix, p. 461.
1871. *Lycopodites Richardsoni* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 34, pl. vii, fig. 81.
1880. *Lycopodites Richardsoni* Dn., Lesquereux, Coal Flora, vol. ii, p. 362.

Known by thick, smooth, or irregularly ribbed axes bearing alternate, stout, compact, boat-shaped, fertile branches, which are a little distant, not in the same plane on both sides of the axis, of generally lanceolate outline, more or less oblique, strongly concave or hollow ventrally, round-carinate dorsally, slightly incurved at the apex, and which consist of a very thick fleshy keel, broadly carinate in the larger specimens, bearing on either side, on its ventral surface, a row of alternating small, thick, oblong, or oblong-lanceolate, often slightly crescentic, scales or bracts; bracts fleshy at base where coalescing with the thicker midrib, dorsally convex, and more or less distinctly carinate, the midrib sometimes in a depression, and ventrally concave, arching outward, sometimes longitudinally lineate dorsally, slightly broader just above the often twisted base, and provided, within the point of basal dilation, with a small ventral pit or pocket, probably the seat of a sporangium.

The fossils from Perry belonging to the species described by Dawson as *Lepidostrobus* and *Lycopodites Richardsoni* are found to represent a type of supposed fructification which is both interesting and new, though insufficient to

show certain essential details indispensable to their proper interpretation and classification. It is not yet definitely ascertained even to what order of plants the new genus here described is referable. Nevertheless certain of its features are so well marked and so striking as to make the type readily recognizable even in small fragments, thus rendering it, as a specialized type of reproductive organ, at once available for stratigraphic purposes. It is hoped that further discoveries in formations of its age may throw light on its vegetative features and its systematic relations.

In the accompanying illustrations and remarks the features presented by the types in hand will be noted, together with such interpretations as the specimens appear to warrant.

The example represented by Pl. IV, Fig. 5, shows portions of a faintly lineate but otherwise smooth axis, on the right of which are three of the boat- or canoe-shaped branchlets that have the general aspect of young fern pinnæ. A better view of the uppermost of these, enlarged to twice the natural size, is shown in Fig. 5a. This exhibits the characteristic form of the pinna (?) and the shape of the dorsally convex lobes or bracts, like the ribs of a canoe, within which, in this instance, the midribs are slightly depressed. The basal union of the bracts with the keel of the pinna or strobilus is not well seen. This specimen, which, together with the two next to be described, belongs to the Portland Society of Natural History, may be regarded, I believe, as a young stage of the fertile plant.

A specimen which appears to represent a more advanced stage of the same species is shown in Fig. 6. Here we see fragments of an axis of slightly greater width than before supporting portions of eight branchlets arranged spirally and not in the same plane, those on the left being revealed by a fortunate cross fracture of the sandstone. This specimen shows that the branchlets or pinnæ, described by Dawson as cones, are not borne in one row on one side only of the axis, as stated in his later descriptions. The branchlets on the right are fractured longitudinally in or near the keel, and the view is therefore lateral and ventral. The greater portions of the bracts are broken away, but the specimen is particularly interesting as showing, in the second branchlet on the right, the pits or pockets at the bases of the pinnules on the borders of the very broad and thick keel. These pits are, I believe, sporangial. It is not certain, however, that they did not contain naked spores, as in certain of the lepidophytes. The details of the scales, which seem to be somewhat pointed at the base, are not well shown in this specimen, though the vascular system is distinctly indicated at numerous points. The branchlets, which should perhaps be called strobili, in this example correspond in size and arrangement to the specimen figured in dorsal or external view by Dawson in pl. xvii, fig. 1, vol. 19, of the Quarterly Journal of the Geological Society of London, 1863.

The fragment of a large branchlet shown in Pl. IV, Fig. 7, represents the form first figured by Dawson[a] as *Lepidostrobus Richardsoni*. It illustrates, in dorsal view, the very thick, broadly carinate, midrib or keel, along which the lobes or bracts, which are close though distinct throughout the greater part of their length, stand like the lobes of a *Pterophyllum*. It is not possible to make out clearly any sporangial pits in this specimen, but I assume that it also represents the fertile plant, in which after the discharge of the spores the bracts, instead of retaining their position in the canoe-shaped strobilus, have spread out nearly in the plane of the keel. The great thickness of the keel argues against the consideration of this specimen as sterile. An imperfect fragment, intermediate in proportions between the specimens last described, is No. 3335 of the fossil-plant collection of the Museum of Comparative Zoology, Harvard University.

As representing perhaps the youngest stage of the fertile branchlets of this plant, I show in Fig. 9 a small specimen which is to be compared with pl. vii, fig. 81a, of Dawson's Fossil Plants of the Devonian and upper Silurian. Even in this little specimen the features of the bracts or lobes, which are comparable to those in Fig. 5, may be seen, while there are also indications of the sporangial pits.

From the foregoing descriptions it will be seen that we have in *Barinophyton* a type of vascular cryptogam in which the fertile specimens consist of stout, apparently smooth axes, carrying alternately, though not in the same plane, short, dense, canoe-shaped branchlets or strobili (pinnæ?), composed of a very thick rachis or keel supporting two opposite rows of alternate fleshy bracts (or pinnules?), each marked at its base by a depression for the protection of the sporangium or spores.

As to whether these fossils represent ferns or lepidophytes I am unable at present to determine. From the mode of attachment of the bracts, their fleshy composition, and the position of the sporangiferous depressions at the base, I am disposed to regard the genus as lepidophytic. In this connection it is of interest to consult *Barinophyton perrianum*, next to be described. Mention may also be made of the faint aspect of ligular pits on the ventral faces of the scales in *B. perrianum*. On account of the coarseness of the matrix the evidence is, however, too obscure for illustration or further description. On the other hand, it is perhaps less difficult to see in the smooth axis and the lateral pinnæ with short, very fleshy rachises, the fertile fronds of a fern in which the thickened, coriaceous, alternating, and somewhat reduced pinnules or lobes partially envelop sporangia at their bases.

It should here be stated that in the material before me I have seen neither indication of dichotomy, as described by Dawson, nor sterile branches of the type shown

[a] Canadian Naturalist, vol. 6, 1861, p. 174.

by him in pl. xvii, fig. 2, of the Quarterly Journal. That dichotomy may, however, occur in this species is rendered probable by its occurrence in another species from the Devonian of New South Wales. A careful comparison of the description and figures published by Prof. W. S. Dun[a] as "*Pecopteris* (?) *obscura*" from Genoa River leaves little room for doubt as to the identity of the latter with *Barinophyton*. In *Barinophyton obscurum* we seem to have almost precisely similar oval, more or less distinctly boat-shaped, "pinnæ," similarly lobed and similarly arranged on a smooth rachis, which, in the largest specimen figured by Dun, appears to be dichotomous. It is possible that the specimen described by Dawson[b] as *Ptilophyton Thompsoni* from the Devonian of Scotland also represents the genus *Barinophyton*.

Barinophyton perrianum D. W.

Pl. IV, Figs. 10, 10[a].

Fertile branchlets, small, oblong, 1 cm.–2 cm. long, 5 mm.–8 mm. wide, slightly upturned at the ends, the scales or lobes short, thick, fleshy, ovate, obtuse, or acute, somewhat constricted and twisted at the base, dorsally convex and carinate; sporangia probably relatively large.

The specimens in hand differ from *Barinophyton Richardsoni* by the straighter branchlets or strobili, the narrower keel, and the relatively short, thick, ovate, fleshy scales or lobes. The general features of the specimens are shown in Pl. IV, Fig. 10. On this fragment of shale three of the strobili are compressed laterally so that the two rows of scales are in part superimposed. A portion of the fourth is seen in ground plan, though several of the scales are slightly dislocated in the compressed shale. It will be noted that the keel or axis of the strobilus is alternately lobed, the scales being attached to the lobes. From the examination of the specimens in hand it is not clear whether the scales protected sporangia or naked spores; but it is possible that sporangia of the type shown in fig. 13, found frequently at Perry, may belong to this or the preceding species.

From an examination of fig. 22 on pl. xxiv of the second part of Dawson's Fossil Flora of the Erian and Upper Silurian of Canada, 1882, provisionally referred by him as the fruit of *Arthrostigma*, I am strongly inclined to believe that the specimen from Campbellton there shown is *Barinophyton* and is but slightly different from, or perhaps identical with, *B. perrianum*, whose scales appear somewhat rounded and imbricate in certain conditions of fossilization. The close relation of the Campbellton plants to *B. Richardsoni* was also noted by Dawson[c] in 1883.

[a] Records Geol. Survey New South Wales, vol. 5, pt. 3, 1898, p. 118, pl. x, figs. 1, 2; pl. xi, figs. 6, 8.
[b] Canadian Naturalist, vol. 8, 1878, No. 7, pp. 385–386.
[c] Canadian Naturalist, vol. 10, No. 1, p. 11.

LYCOPODITES Brongniart.

Classific. Vég. Foss., 1822, p. 9.

LYCOPODITES COMOSUS Dn.

1862. *Lycopodites* sp., Dawson, Quart. Jour. Geol. Soc. London, vol. xviii, opp. p. 329.
1863. *Lycopodites comosus* Dawson, Proc. Portland Soc. Nat. Hist., vol. i, pt. 2, p. 100, pl. ii, fig. 2.
1863. *Lycopodites comosus* Dawson, 2d Rept. State Geol. Me., p. 403.
1863. *Lycopodites comosus* Dawson, Quart. Jour. Geol. Soc. London, vol. xix, p. 462, pl. xvii, fig. 14.
1871. *Lycopodites comosus* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 35.

Stem stout, not observed to branch, densely covered with long filiform leaves.

This species is known to me only by Dawson's description, quoted above, and the figure of a single small fragment published by him in 1863. Its generic determination appears to be somewhat doubtful.

LEPTOPHLŒUM Dawson.

Rept. St. Geol. Me., 1861 (1862), p. 249.

LEPTOPHLŒUM RHOMBICUM Dn.

Pl. VI, Figs. 1–4.

1861. *Sternbergia* sp., Dawson, Can. Nat., vol. vi, No. 3, p. 175.
1862. *Sternbergia* sp., Dawson, in Hitchcock, Rept. St. Geol. Me., 1861, p. 248.
1862. *Leptophlœum rhombicum* Dawson, Rept. Nat. Hist. and Geol. Me., 1861, p. 249, figs. 3, 4.
1862. *Leptophlœum rhombicum* Dn., Hitchcock, Rept. Nat. Hist. and Geol. Me., 1861, p. 248.
1862. *Leptophlœum rhombicum* Dawson, Proc. Portland Soc. N. H., vol. i, pt. 1, pp. 76, 77, pl. i, figs. 1, 2.
1862. *Leptophlœum rhombicum* Dawson, Quart. Jour. Geol. Soc., vol. xviii, pp. 298, 316, pl. xii, fig. 8; pl. xvii, fig. 53.
1863. *Leptophlœum rhombicum* Dawson, Am. Jour. Sci., 2d ser., vol. xxxv, p. 462, pl. xviii, fig. 19.
1863. *Leptophlœum rhombicum* Dawson, Proc. Portland Soc. N. H., vol. i, pt. 2, p. 100.
1863. *Leptophlœum rhombicum* Dawson, Second Rept. Nat. Hist. and Geol. Me., 1862, p. 404.
1863. *Leptophlœum rhombicum* Dn., Logan, Geol. Canada, p. 885.
1870. *Leptophlœum rhombicum* Dawson, Nature, vol. ii, p. 86, fig. 2.
1871. *Leptophlœum rhombicum* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., pp. 36, 85, pl. viii, figs. 88, 89.
1872. *Leptophlœum rhombicum* Dawson, Proc. R. Inst., vol. vi, p. 168, fig. 2.
1873. *Leptophlœum rhombicum* Dawson, Quart. Jour. Geol. Soc., vol. xxix, p. 369.
1878. *Leptophlœum rhombicum* Dn., Etheridge, Cat. Australian Foss., p. 31.
1880. *Leptophlœum rhombicum* Dn., Lesquereux, Coal Flora, vol. i, p. 460.
1880. *Leptophlœum rhombicum* Dawson, Chain of Life, p. 98, fig. 90.
1882. *Leptophlœum rhombicum* Dawson, Foss. Pl. Erian and Upp. Sil. Can., pt. 2, p. 105.
1887. *Leptophlœum rhombicum* Dn., Solms-Laubach, Einl. d. Paläophytol., p. 205.
1888. *Leptophlœum rhombicum* Dn., Johnston, Geol. Tasmania, p. 81 (syn. in part).
1888. *Leptophlœum rhombicum* Dn., Schenck, Foss. Pflanzenreste, p. 64.
1862. *Stigmaria* sp., Dawson, Quart. Jour. Geol. Soc., vol. xviii, opp. p. 329.
1863. *Stigmaria pusilla* Dawson, Proc. Portland Soc. Nat. Hist., vol. i, pt. 2, p. 100, pl. ii, fig. 1.
1863. *Stigmaria pusilla* Dawson, Second Rept. Nat. Hist. and Geol. Me., 1862, p. 403.

1863. *Stigmaria pusilla* Dawson, Quart. Jour. Geol. Soc., vol. xix, p. 460, pl. xvii, fig. 3.
1871. *Stigmaria pusilla* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., pp. 23, 88, pl. iii, fig. 31.
1888. *Stigmaria pusilla* Dn., Renault, Notice sur les Sigillaires, pp. 31, 43.
1863. *Cyperites* sp., Dawson, Quart. Jour. Geol. Soc., vol. xix, p. 460.
1871. *Cyperites* sp. Dawson, Foss. Pl. Dev. and Upp. Sil. Can., pp. 24, 88.
1894. *Bergeria* sp., Nathorst, Zur Foss. Fl. d. Polarländer, vol. i, th. 1, p. 14, pl ii, fig. 8.

Trees of small size, dichotomously branching; trunk covered with more or less distinctly marked rhomboidal leaf cushions of relatively large size; leaf cushions or bolsters spirally arranged, nearly contiguous, nearly exactly rhomboidal, the transverse diameter being usually longer, the surface being nearly flat, often more prominent at the proximal angle, which is generally obtuse, the lateral angles somewhat acute, the distal margin being generally concave on either side of the usually slightly acute apex; leaf scar very small, situated a little above the middle of the cushion, oval or ovate, about one-eighth of the width and one-fifth of the altitude of the bolster, narrowly annulate, with a mammillary nerve trace a little above the middle; bolster provided within the distal angle by a slightly depressed, often umbilical, ligular pit, the border of which is radiately corrugated; leaves acicular, slender, attaining a width of about 0.75 mm. and a length of 5 cm. or more, dorsally prominently carinate; fructification not correlated.

Leptophlœum rhombicum was one of the first species to be described from Perry. The salient features of the plant are the relatively large size of the bolsters as compared with the diameter of the stem; and the small oval or ovate leaf scar placed near the center of the nearly flat, very broadly rhomboidal, field. The general aspect of the stems is that of Presl's *Bergeria*, with which Count Solms-Laubach and others have compared this species. In reality the stems seem to present bolsters of the lepidodendroid type, on which are nearly centrally placed leaf scars, probably closely similar to those of *Bothrodendron*. The bolsters, which are nearly contiguous, are generally somewhat tilted with reference to the plane of the stem surface.

In some specimens of this species the cortex is wrinkled so as to produce a slight transverse corrugation. This is most excellently illustrated in the original example $\frac{43}{1}\frac{94}{4}$ in the geological collections of the American Museum of Natural History of New York. As will be seen in the new drawing of this specimen, Pl. VI, Fig. 1, the bolsters in the upper part of the middle third of the fragment are laterally traversed by shallow and narrow transverse creases. The latter pass through the lateral angles of the bolsters and cross the fields near the leaf scars, which in a few instances they nearly conceal. The creases or wrinkles of the outer cortex are thus regular in occurrence, there being two spaces to the height of each bolster, while the line of fold is sinuate in consequence of the originally curved surface of the bolsters. The result is the production of a nodal effect, though the regularity of the phyllotaxy is clear. It was precisely this nodal aspect, which appears more distinctly when viewed

longitudinally, that led Dawson to describe and illustrate this part of the specimen as a *Sternbergia* and to argue for the existence of a *Sternbergia* pith in certain of the Lepidophytes. It is probably a longitudinal contraction of the outer cortex, due to shrinkage of the inner cortex or subcortical tissue. Its uniform periodicity with reference to the height of the leaf scar and the adaptation of the curve to the curvature of the bolsters show that this creasing or transverse corrugation can not be due to chambering of the pith. A close inspection of the type shows the regularity of the leaf scars in the usual quincunxial phyllotaxy throughout. I can find no evidence in the specimen in support of the theory of a chambered pith. In this respect the opinions of Carruthers, Solms-Laubach, and Schenck are well founded. It will be seen that there is slight evidence of zones of foreshortened bolsters, such as are common in several of the Devonian and earliest Carboniferous lepidophytes, as, for example, in Carruthers's *Lepidodendron nothum*, from the Devonian of Queensland, or the large fragment from the Tanner-Grauwacke figured by Potonié[a] as *Cyclostigma hercynicum*.

The general aspect of the bolsters is shown in three specimens illustrated in the numerous publications in which this species was treated by Dawson. These are in close accord with our specimens, as well as with another of the original specimens of Dawson, No. $4\frac{3}{2}\frac{0}{1}\frac{4}{4}$ of the American Museum of Natural History, kindly loaned me for comparison.

Of the detail of the leaf scars little is known, on account of their small size and the coarsely granular composition of the matrix. It is clear, however, that the scar is marked by a very narrow border. The upper margin of the scar is not absolutely distinct, and it is possible that it is slightly indented. No clear indications of parichnoi or appendages have yet been observed. In general the leaf scars would appear to be most directly comparable to those of *Bothrodendron*.

The large size sometimes attained by the bolsters of this plant is shown in the fragment, Pl. VI, Fig. 2. In this the proportional altitude is greater than in most fragments seen. In Fig. 4 is shown a large fragment of stem in which the bolsters are compressed laterally and stretched in the longitudinal sense. This specimen is interesting as showing a rugose, faintly striate, subcortical or subepidermal structure in which the nerve traces also may be seen. It is probable that the narrow subcylindrical impression traversing the fragment represents the central woody axis, the nodal appearance being caused by impression on the underlying bolsters. This phase of the stem finds a corresponding state in certain examples of *Lepidophloios*.

None of the specimens which have come under my notice show indications of

[a] Abhandl. K. preuss. geol. Landesanstalt, new series, vol. 36, 1901, p. 35, fig. 24.

branching or of leafy twigs or cones, such as are figured by Dawson.[a] The original of the figure of a branch published by him I have not seen, but if it is correctly illustrated it precludes the reference of such forms as *Lepidostrobus globosus* to this species, as might otherwise be suggested on the circumstantial evidence of their association in the same bed. I should also add that the leaves or leaf fragments described by Dawson or contained in our collections, on account of their narrow forms, corresponding in width to the leaf scars, and their association in the same bed, are assumed to belong to the species described above. None have, I believe, been found attached to the large bolsters.

In some of the cortical fragments the relief of the bolsters is so slight that they are visible only under proper illumination. The cuticle illustrated by Dawson[b] as *Stigmaria pusilla* appears to represent such a portion of *Leptophlœum rhombicum*, and it is accordingly here included under the same name. The more rounded form of the scars is hardly different from that seen on some of the more distinctly marked fragments of *Leptophlœum* stems.

The species of Palæozoic plants to which *Leptophlœum rhombicum* is most closely related is undoubtedly that described and illustrated by Carruthers,[c] Feistmantel,[d] and others as *Lepidodendron nothum* Unger. The latter plant, while evidently different from Unger's uncertainly defined species,[e] has been regarded by a number of paleobotanists, including Carruthers and Solms-Laubach,[f] as identical with the Perry plant. The concordant characters in support of this union of the two species are certainly both striking and interesting. One has only to compare our Pl. VI, Fig. 1, of Dawson's original type,[g] or Dawson's illustration of the same specimen, pl. xxvi, fig. 7, of the Eighteenth volume of the Journal of the Geological Society of London, to be at once impressed with the similarity in the aspect of the stem, including both the normal rhombic bolsters and the wrinkled or foreshortened leaf cushions. This superficial agreement is further reenforced by the cicatricule or ligular scar in the apex of the bolster, as shown in figs. 11, 13, and 14 of Carruthers's plate, or the central leaf scars indicated in l. c. 10 of the same plate. There is even a close identity in the outlines of the bolsters as shown in figs. 8 and 9 of the cited plate.

Against the actual identity of these species, which was vigorously opposed by Dawson,[h] we have to mention, first, the singular lepidophylloid leaves shown by Carruthers as attached to the stem; and, second, the apparent absence of the interior leaf

[a] Quart. Jour. Geol. Soc. London, vol. 19, 1863, pl. xviii, fig. 19.
[b] Proc. Portland Soc. Nat. Hist., vol. 1, pt. 2, 1863, pl. ii, fig. 1.
[c] Quart. Jour. Geol. Soc. London, vol. 28, 1872, p. 353, pl. xxvi.
[d] Coal and Plant-Bearing Beds of East Australia and Tasmania, 1890, p. 137, pl. i, figs. 1–4.
[e] Denkschr. K. Akad. Wiss., Wien, math.-nat. Cl., vol. 11, 1856, p. 175. pl. x, figs. 4–8.
[f] Einleitung d. Paläophytologie, 1887, p. 205.
[g] No. $\frac{4300}{4}$ of the collection of the American Museum of Natural History.
[h] Fossil Plants Erian and Upper Silurian Canada, pt. 2, 1882, p. 105.

scars from the cushions in which the cicatricules, which I interpret as ligular, are present in the apices. Carruthers and others appear to regard the apical and the more nearly central scars as identical and as indicating mere variation in the position of the leaf scar. Such an interpretation can not be admitted for our American specimens; in fact, the specimens in hand with normal bolsters fail to show the leaf scars at any considerable distance above the center, such examples as Figs. 2 and 3, or $\frac{4}{2}\frac{3}{0}\frac{4}{4}$ of the American Museum of Natural History being comparable only to fig. 10 of Carruthers's plate, or possibly to the obscure markings shown in one or two of Feistmantel's figures. In the Perry type, Pl. VI, Fig. 1, obscure traces of leaf bases are possibly present, but they are not sufficiently clear for delineation. Nothing of the special form shown by Carruthers is present. The American plant differs also in the absence of carination in the bolsters, such as is shown in fig. 9 of the plate.[a] The Perry plant appears to be also related to the *Lepidodendron australe* of McCoy,[b] with which the Queensland plant of Etheridge, referred to above, is regarded as identical by Etheridge[c] and Kidston,[d] though both of these authors recognize the separation of *Leptophlœum rhombicum*. Both of the Australian stems, which in some cases seem to have been associated, are, I believe, to be referred to the genus *Leptophlœum*. To the same group, if not to *L. rhombicum* itself, is to be referred the fossils from the region of the Ogur, in eastern Siberia, described by Schmalhausen[e] as *Bergeria*.

In the first part of Nathorst's Paläozoischen Flora der Arktischen Zone there is figured as *Bergeria* a specimen from the Devonian of Spitzbergen which, so far as its details are given, appears to conform so completely with *Leptophlœum rhombicum* that it is difficult to regard it as not belonging to the same species.

The type specimens of *Leptophlœum rhombicum* are Nos. $\frac{4}{1}\frac{3}{0}\frac{4}{4}$ and $\frac{4}{2}\frac{3}{0}\frac{4}{4}$ of the American Museum of Natural History.

LEPIDOSTROBUS Brongniart.

Prodrome, 1828, p. 87.

LEPIDOSTROBUS? GLOBOSUS DN.

Pl. VI, Figs. 5, 5*a*.

1862. *Carpolithes sp.*, Dawson, Quart. Jour. Geol. Soc. London, vol. xviii, opp. p. 329.

1862. *Lepidostrobus globosus* Dawson, Quart. Jour. Geol. Soc. London, vol. xviii, p. 298.

1863. *Lepidostrobus globosus* Dawson, Am. Jour. Sci., 2d ser., vol. xxxv, p. 313.

1871. *Lepidostrobus globosus* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 35.

1884. *Lepidostrobus globosus* Dn., Lesquereux, Coal Flora, vol. iii, pp. 850, 893.

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[a] Several of the figures in Etheridge's original paper are reproduced in Etheridge and Jack, Geology and Paleontology Queensland, 1892, p. 196, pl. v.

[b] Prodrome Paleontology Victoria, dec. 1, 1874, p. 37, pl. ix.

[c] Records Geol. Survey New South Wales, vol. 2, 1891, pt. 3, p. 119.

[d] Jack and Etheridge, Geology and Paleontology Queensland, 1892, p. 196.

[e] Bull. Acad. Roy. St. Petersburg, Mél. phys. et chem., vol. 9, 1876, pp. 630, 631, pl. xx, figs. 5, 6.

1863. *Carpolithes spicatus* Dawson, Quart. Jour. Geol. Soc. London, vol. xix, p. 461, pl. xvii, fig. 15.
1871. *Carpolithes spicatus* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 62.
1880. *Carpolithes spicatus* Dn., Lesquereux, Coal Flora, vol. ii, p. 598.
1888. *Carpolithes spicatus* Dn., Schenk, Foss. Pflanzenreste, p. 99.

Small, oblong bodies, consisting of a very broad fleshy axis about 5 mm. in width, traversed by a slender strand; bracts close, very small, about 2 cm. in length, ovate, acute or acuminate, concavo-convex, arching upward above the middle, dorsally broadly carinate; sporangia unknown.

The specimen illustrated in Pl. VI, Fig. 5, is one of only two specimens of this type in our collections. As shown in the enlarged detail, Fig. 5ª, the scales are proportionally very broad toward the base and are pocketed in the flexure. A peculiar feature suggestive of *Leptophlœum* and some forms of *Lepidophloios* is the small axial strand seen in Fig. 5ª. It is not clear in the specimen before me whether the scales surrounded the axis or were confined to the lateral borders of a flat medial body, but the former appears much more highly probable, and, in fact, such an arrangement must have been present in Dawson's type of the species.

In the absence of knowledge of the definite arrangement of the scales and sporangia it is impossible to determine the exact nature of the fossil in hand. But from the form of the scales and the indications of attendant sporangia I am disposed to regard it as perhaps belonging to *Lepidostrobus*. If such it proves to be, it may eventually be correlated with *Leptophlœum rhombicum*. The bracts have somewhat the aspect of the smallest scales of *Barinophyton perrianum*. It is possible, however, that they are but dense chaffy scales on the rachis of a young fern.

In portions of the specimens the scales arch upward so as to appear like small ovate or roundish bodies on the borders of the axis. To this appearance is doubtless due the description, as *Carpolithes spicatus*, of a specimen[a] which can hardly be other than the same species as the example here figured. I therefore do not hesitate in uniting the species referred to with that from the same type locality very briefly described, without illustration, as *Lepidostrobus globosus*. The aspect of the profile of these specimens suggests that the record of the occurrence of *Lepidoden-* [illegible] at Perry may possibly have been based on a similar fragment.

LEPIDOCYSTIS Lesquereux.

Coal Flora, Atlas, 1879, p. 13.

LEPIDOCYSTIS SILIQUA (Dn.) D. W.

[illegible] *Carpolithes* Dawson, Quart. Jour. Geol. Soc. London, vol. xix, p. 465, pl. xvii, fig. 4.
[illegible] Dn., Lesquereux, Coal Flora, vol. ii, p. 598.
[illegible] Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 62, 86.

[illegible] probably the fruit of *Arthrostigma gracile*: Fossil Plants Devonian and Upper Silurian [illegible]

Oblong to linear-oblong, 1.5–4 cm. long, 3.5–8 mm. wide or 15 mm. in width when spread out, rounded or truncate-rounded at one end, usually slightly arcuate, obtuse or obtusely rounded at the other end, thinly carbonaceous, minutely granulose.

This species, described by Dawson as *Carpolithes siliqua*, appears to be represented by numerous specimens, the largest of which has nearly the proportion and form illustrated in the figure given by Dawson. The greater number, however, are but about one-half the length of the latter, the width being nearly the same as in Dawson's original. In one of the specimens collected last year and another in the cabinet of the Portland Society of Natural History the sporangium is spread out so as strongly to resemble the specimens described by Lesquereux as *Lepidocystis fraxiniformis* (Goepp.), to which the Perry plant was compared by him. The sporangium wall is relatively thick and destitute of structural features, though, in a few instances, a very fine and faint striation, perhaps due to the cell arrangement in rows, is, under a strong lens, discernible. On account of the coarseness of the matrix it is impossible to differentiate the sporangial contents. A few small megaspores, 0.4 mm. in diameter when flattened, and minutely granulose or obscurely meshed, are found in association. The latter are perhaps indistinguishable from *Sporangites Jacksoni*.

Like the lepidocysts of the lower Mississippian, these specimens vary greatly in dimensions, and, while they seem to be true spore cases, they do not agree in uniformity of size or of form with the species of *Lepidostrobus* in the Coal Measures, and it is not certain that they are referable to any recognized lepidophytic type. On the contrary, it is not impossible that they belong to quite another, and perhaps lower, group of plants.

LEPIDOCYSTIS INQUISITUS D. W.

Pl. IV, Figs. 12, 13, 14.

Sporangia small, asymmetrically ovate to oblong, slightly arcuate, 4–8 mm. long, 2–3 mm. wide, somewhat wider and more broadly rounded at one end, narrowing a little toward the other end, minutely granular-carbonaceous.

The general aspect and the variation in form of these spore cases are shown in Pl. IV, Figs. 12, 13, and 14. The coarsely granular matrix renders it impossible to discern the characters of the spores. The fossils are rather densely carbonaceous, and this fact, taken with the variation in form, led me at first to think they might be mere waterworn pieces of wood. But they lack traces of the fibrous texture of wood and are not sufficiently thin to represent fragments of cuticle. Moreover, nearly all show the inequality of the ends and the arching. Consequently they are, I believe, to be regarded as sporangia. In general they appear to be of the same nature as the *Lepidocystis siliqua* described above, the chief differences being the

much smaller size, proportionally broader form, and more delicate texture. It appears probable therefore that these two species are congeneric. It is possible, however, that *L. inquisitus* may have been derived from some such type as *Barinophyton Richardsoni*.

SPORANGITES Dawson.

Can. Nat., vol. viii, 1863, p. 454.

SPORANGITES JACKSONI D. W.

Pl. VI, Figs. 6, 6ª.

Spore masses oblong or elongated, attaining a length of 4 cm. or more, and a width of 1 cm.; megaspores of irregular form, due to compression, averaging about 4 mm. in diameter as flattened, not very rigid, minutely shagreened, and marked by a small mamillate point.

Among the fossils placed in my hands through the courtesy of the Boston Society of Natural History, I have found a portion of an agglomeration of megaspores partially exposed at the edge of one of the rock fragments, No. 6687 of the society's paleontological collections. The removal of a portion of the covering matrix revealed what appears to be two partially overlapping spore masses, as shown in Pl. VI, Fig. 6. They consist of a slightly brownish rock medium, not very densely crowded with the large and somewhat irregularly shaped spores, as illustrated in the enlarged Fig. 6ª. The spores are very finely shagreened and seem to be marked by a small mamillate point. The thickness of the compressed spore mass in the center was nearly 2.5 mm. From the disposition of the spores and the form of the masses I am disposed to regard the former as practically in place, and the mass as the undisturbed contents of large spore sacs, the full size of which is not shown in these specimens. It is possible that they may have been derived from a lepidocyst of the type of *Lepidocystis siliqua*, though specimens of that species seem in general not so large. Such a correlation is slightly favored by the presence of a single similar spore on a shale fragment nearly in contact with an example of the same form. However, it is possible, on the other hand, that the spore agglomeration is of quite different origin. It is not possible from the specimens in hand to ascertain whether spores of more than one kind were contained in the same mass.

The specimens of *Sporangites Jacksoni* are larger and less rigid than those of *Sporangites Huronensis* Dn. of the Genesee shale, or the other megaspores from Perry described by Dawson.

The species is named in honor of Dr. C. T. Jackson, the first geologist of Maine.

CORDAITES Unger.

Gen. et Sp. Pl. Foss., 1850, p. 277.

CORDAITES FLEXUOSUS Dn.

1862. *Cordaites* sp., Dawson, Quart. Jour. Geol. Soc. London, vol. xviii, opp. p. 329.
1863. *Cordaites* (*Pychnophyllum*) *flexuosus* Dawson, Proc. Portland Soc. Nat. Hist., vol. i, pt. 2, p. 100, pl. ii, fig. 4.
1863. *Cordaites flexuosus* Dawson, 2d Rept. Nat. Hist. and Geol. Me., p. 403.
1863. *Cordaites* (*Pychnophyllum*) *flexuosus* Dawson, Quart. Jour. Geol. Soc. London, vol. xix, p. 462, pl. xvii, fig. 9.
1871. *Cordaites flexuosus* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., pp. 44, 85.
1880. *Cordaites flexuosus* Dn., Lesquereux, Coal Flora, vol. ii, p. 544.

Leaves lanceolate, acuminate, broad at the base; nerves numerous, parallel, somewhat sinuous and uneven.

In the collections before me I have seen but a single fragment which would appear to be referable to this little-known species, first described from Perry. The specimen in hand, while appearing to represent the form described by Dawson, offers nothing in support of the reference of the fossil to the genus *Cordaites*.

Not having seen the original type, I quote the diagnosis given by Dawson. No other example has, so far as I am aware, been figured or described. The inclusion of this species in *Cordaites* by Dawson was regarded by him as provisional, its true affinities being "quite uncertain."

CORDAITES? ANGUSTIFOLIUS Dn.

1861. *Cordaites angustifolius* Dawson (non Lx.), Can. Nat., vol. vi, pp. 170, 176, fig. 11*c*.
1862. *Cordaites angustifolius* Dawson, Quart. Jour. Geol. Soc. London, vol. xviii, p. 318.
1863. *Cordaites angustifolius* Dn., Logan, Geol. Canada, pp. 394, 399, fig. 428.
1868. *Cordaites angustifolius* Dawson, Acad. Geol., pp. 534, 546.
1871. *Cordaites angustifolius* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., p. 44, pl. xiv., fig. 163.
1880. *Cordaites angustifolius* Dn., Lesquereux, Coal Flora, vol. ii, p. 544.
1882. *Cordaites angustifolius* Dawson, Foss. Pl. Erian. and Upp. Sil. Can., pt. 2, p. 106.
1889. *Cordaites angustifolius* Dawson, Trans. R. Soc. Can., vol. vi., sec. 6, pp. 29, 34.

Portions of very slender, rather thick, straight or gently curved leaves, 3–5 mm. in width, exceeding 8 cm. in length, regularly lineate with fine, parallel, distinct, longitudinal nerves; apical and basal portions of the leaves unknown.

The fragments which are here provisionally placed under this name appear to conform with the characters of the specimens described and figured by Dawson from Gaspé.

Little can be said of the real nature of the plants included in this species.

Some of them may be fern stems. The species is stated by Dawson[a] in one of his later papers to be of a doubtful nature.

The plants from St. John included by Dawson in the same species represent an entirely distinct type.

CARPOLITHES Schlotheim.

Petrefaktenkunde, 1820, p. 418.

CARPOLITHES CONFINIS D. W.

Pl. IV, Fig. 11.

1871. *Carpolithes?* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., pp. 64, 90, pl. x, fig. 125.

Ovate, about 6 mm. in length and 4.5 mm. in width a little below the middle, asymmetrical, curved slightly to one side, very obtuse, obscurely apiculate, attached by more than one-half its width, nearly flat in the impression, lineate parallel to the border, more strongly marked toward the base.

The fossils above described are tentatively placed in the genus *Carpolithes*, although from the evidently broad attachment irregularly fractured at the base, as shown in Pl. IV, Fig. 11, and from the rather thick substance there would appear to be some reason for regarding them as merely scales, possibly comparable to those of *Barinophyton perrianum*. The broad basal attachment, the asymmetrical form, and the absence of all traces of a border argue against the reference of the type to the genus *Cardiocarpon*.

From a comparison of the details of the figure of a specimen from Gaspé published by Dawson,[b] with doubt as to whether the object was a carpolite or a concretion, I am disposed to regard it as identical with the species in hand.

CARPOLITHES LUNATUS Dn.

1863. *Carpolithes lunatus* Dawson, Quart. Jour. Geol. Soc. London, vol. xix, p. 464, pl. xvii, fig. 11.
1871. *Carpolithes lunatus* Dawson, Foss. Pl. Dev. and Upp. Sil. Can., pp. 63, 86.
1880. *Carpolithes lunatus* Dn., Lesquereux, Coal Flora, vol. ii, p. 598.

Base rounded regularly, apex broadly truncate and mucronate; nucleus surrounded with a narrow margin.

I have seen no specimens representing this form, described by Dawson, as above, from a single specimen found at Perry. From the figure given by the author the systematic position and even the nature of the fossil would appear to be absolutely uncertain. In form and size it closely simulates a bolster of one of the Devonian Bergeria-Lepidodendra.

[a] Am. Jour. Sci., 3d ser., vol. 38, July, 1889, p. 8.
[b] Fossil Plants Devonian and Upper Silurian Canada, pl. x, fig. 125, p. 64.

STEMS—DADOXYLON?

I find in the various collections a number of specimens labeled, apparently by Dawson, as *Dadoxylon* and "stems of *Cordaites*." One of these, in the collection of the Portland Society of Natural History, is the counterpart of the specimen well figured in Dawson's paper on Further Observations on the Devonian Plants of Maine, Gaspé, and New York.[a] It is simply an impression, and promises nothing further regarding the structure of the stem itself. Other examples appear to represent long, straight fragments of striate or lineate stems, one of which has a width of over 3 cm.

These fragments are of little value and I suspect are paleontologically indistinguishable from the material from the Chemung of New York earlier described as *Rhachiopteris cyclopteroides* Dn.[b] The latter species was never figured and is not at present identifiable by the literature. No further description of gymnospermous woods from the Perry beds seems to have anywhere been published,[c] and none of the specimens that have passed through my hands appear to offer sufficient characters for a generic identification.

ADDITIONAL PLANTS.

The following additional plants were reported by Sir William Dawson from Perry, but were not seen by the writer and are not included in the preceding review:

Aporoxylon, recorded,[d] but not figured nor identifiably described.

Calamites sp., entered in the Maine column of the table, Fossil Plants Devonian and Upper Silurian Canada, 1871, page 85; probably by error, since it is not elsewhere mentioned in the literature relating to Maine.

Caulopteris Lockwoodi Dn., of the Devonian at Gilboa, N. Y., is similarly entered in the Maine column only, but is nowhere else mentioned in connection with material from Maine. The entry is evidently an error.

Filicites incertæ sedis, published in 1863,[e] belongs to the genus *Otidophyton*, and possibly to *O. hymenophylloides*, though regarded by Dawson as possibly belonging to *Platyphyllum Brownianum*.

Hymenophyllites sp., not recognizably described and not illustrated, appears to have been abandoned after its first publication in 1863.[f] It may be a young fertile pinna of *Archæopteris*.

Lepidodendron gaspianum, reported by Dawson[g] as represented from Perry in

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[a] Quart. Jour. Geol. Soc. London, vol. 19, 1863, p. 460, pl. xviii, fig. 20.

[b] Quart. Jour. Geol. Soc. London, vol. 18, 1862, p. 323.

[c] Loc. cit., opp. p. 329. Proc. Portland Soc. Nat. Hist., vol. 1, pt. 2, 1863, p. 100. Second Rept. Nat. Hist. and Geol. Me., 1862 (1863), p. 460.

[d] Quart. Jour. Geol. Soc. London, vol. 18, 1862, pp. 299, 307.

[e] Quart. Jour. Geol. Soc. London, vol. 19, p. 464, pl. xvii, figs. 10, 10b.

[f] Proc. Portland Soc. Nat. Hist., vol, 1, pt. 2, p. 100.

[g] Canadian Naturalist, vol. 1, No. 3, 1861, p. 174.

Archæopteris Jacksoni, also found in the Devonian at Scaumenac and Restigouche Bay, is closely related to *A. minor* of the Catskill and Chemung in Pennsylvania, and in sterile forms is not readily distinguished from *A. gaspiensis*. *A. Rogersi*, present in the Chemung of New York and at Montrose and Meshoppen in Pennsylvania, is very closely related to *A. Roemeriana* of the upper Devonian of Europe and the Arctic regions. The development and position of the sporangia in *A. Hitchcocki* relate the species intimately to the fructification described as *Sphenopteris condrusorum* from the upper Devonian of Belgium, and, less closely, to the fructification of *A. minor* of the Catskill of Pennsylvania. A plant from the upper Devonian of Belgium having the aspect of that here described as *Otidophyton* has been referred by Crépin to *A. hibernica*.

The peculiar type of plant described as *Barrandeina perriana* is perhaps identical with that from the Hamilton of New York figured by Dawson as "*Cordaites?*", while it is otherwise most nearly comparable to the *B. Duslianum* from Barrande's H–h1 stage. Both the genus *Barrandeina*, to which I have referred the species, and *Anarthrocanna*, under which Dawson placed it, are upper Devonian genera.

Rhachiopteris pinnata is also from the middle Devonian of New York, while *R. punctata*, which is doubtfully recorded in the Perry flora, occurs in the Ithaca shales of central New York and the Chemung at Gilboa, N. Y.

The plant fragment tentatively referred to *Sphenopteridium* seems to have its relatives in the Devonian of the Rhine region and in the basal lower Carboniferous of Europe. I interpret it as representing a group generally characteristic of the lower Carboniferous.

Dimeripteris is known only from the Devonian. *D. incerta*, found typically in the Hamilton of New York, is possibly inseparable from *D. fasciculata* of the Donetz Devonian, while we find a very closely related form under the name *Cephalotheca mirabilis* in the upper Devonian of Bear Island. *D. recurva* likewise seems to have its only near relatives in the Donetz, though it is possibly closely allied to a form illustrated by Unger from the Cypridina beds of Thuringia. It is, however, comparable in some respects to *Sphenopteris flexilis* Heer, from the basal Carboniferous of Spitzbergen.

Sphenopteris filicula, if correctly diagnosed, belongs to a group of species, including *S. affinis* and *S. moravica*, which is, in general, characteristic of the basal Carboniferous. However, a type extremely similar to that in hand, and perhaps specifically identical, has been figured by Nathorst from the Devonian of Spitzbergen. Both closely resemble material from the American Pocono that has been identified with the *S. flaccida* of the Devonian of Condroz. They should be compared also with Stur's *Sporochnus Krejči* from the H-h1 stage (upper Devonian) in Bohemia.

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All the species described as *Psilophyton*, with the exception of *elegans*, whose generic reference is doubtful, appear to be Devonian, though *Psilophyton princeps* was also reported by Dawson from beds at Gaspé which are regarded by many geologists as lying below the base of the Devonian. It is characteristically a Devonian genus. The specimens which I provisionally place with the smooth-costate group included by Dawson in *Ps. princeps* are by the form of their terminal laminæ most closely bound to the Psilophyta from Campbellton and from the Catskill of New York. The same characters appear in the congeneric *Hostinella hostinensis* from the upper Devonian (H-h1 stage) of Bohemia, and the species of *Psilophyton* of the "Old Red Sandstone" of Scotland. Stem fragments of the smooth *Psilophyton* type are also found in the Devonian of Bear Island and Spitzbergen. *Psilophyton alcicorne* appears to be nearest to the Campbellton material referred by Dawson to *Ps. princeps*, though its real affinities are not known.

The fragment doubtfully referred to *Paleostachya* fails to reveal nodes and the verticillate structure essential to the genus, which is Carboniferous, and has very little stratigraphic value at present.

Barinophyton is a special and very peculiar type, not elsewhere known outside of the Devonian. It is represented by *B. obscurum* in the Devonian of New South Wales, and probably by the plant erroneously described as *Ptilophyton Thompsoni* from the Devonian of Scotland. *Barinophyton Richardsoni* is perhaps present in the Gaspé section.[a] *B. perriana* appears to be present in the Devonian at Campbellton.

The generic characters of the plant named *Lycopodites comosus* by Dawson are not clear, but the general aspect of the fragment as figured is such as is common in the slender branching lepidophytes of the Carboniferous, though species of generally similar aspect are not unknown in the uppermost Devonian. Too little is known of the details of the plant to entitle it to any importance in stratigraphic correlation.

In *Leptophlœum* we have another peculiar lepidophytic type, which appears to combine a bothrodendroid leaf scar with a distinctly lepidodendroid bolster. It is quite distinct from the Bergeria or subepidermal state of *Lepidodendron*. So far as known, *Leptophlœum* is distinctly Devonian. *L. rhombicum* is reported from the middle Devonian of Gaspé and Campbellton, from York River, and the upper Devonian of Queensland. It is present in the Devonian of Spitzbergen and at the so-called Ursa stage of the Ogur region, in eastern Siberia. The remaining species, *L. australe* and *L. nothum* (non Ung.), also occur in the Australian Devonian.

Lepidostrobus globosus is another singular and but little known type which, under the name *Carpolithus spicatus*, is reported from the Chemung of Shamokin, Pa. It is possibly the fertile strobilus of *Leptophlœum rhombicum*.

The supposed lepidophytic spore cases described as *Lepidocystis siliqua* seem to

[a] See Fossil Plants Devonian and Upper Silurian Canada, pl. xii, fig. 154.

be most intimately related to a species in the Pocono (basal Carboniferous) of Pennsylvania. *L. inquisitus*, of slightly doubtful generic reference, is unique in form, and may possibly prove not to be lepidophytic.

The large oblong sporangial masses described under the name *Sporangites Jacksoni* seem in size and form nearest connected with *Lepidocystis siliqua*. It is not entirely clear, however, that they were similarly produced. The megaspores appear to belong to the *Sporangites* type described by Dawson in several species from the Devonian of North and South America. It is doubtful whether the genus, as composed, is distinguishable from some of the megaspores of the Carboniferous.

The generic reference of both of the species referred to *Cordaites* is somewhat uncertain, although the presence, as low as the Hamilton, of fossil woods of the group commonly known as *Dadoxylon* justifies the assumption that very near relatives[a] of the genus *Cordaites*, if not the genus itself, were present in the middle Devonian. The occurrence of typical foliage of the genus is, in general, characteristic of the upper Carboniferous and lower Permian. *Cordaites angustifolius* is reported from the lower Devonian of Gaspé and Campbellton and from the Marcellus of New York.

Carpolithes confinis seems to be present in the Gaspé section. *C. lunatus*, the characters and identity of which, as described in 1863, from Perry, are very obscure, has not been recognized elsewhere.

CORRELATION.

Of the entire flora described[b] from Perry, *Sphenopteris filicula* and *Lepidocystis siliqua* are types which appear to belong to groups more or less distinctly characteristic of the lower portion of the lower Carboniferous. The fragment described as *Palæostachya?* sp., and the forms earlier published as *Lycopodites comosus* and *Carpolithes lunatus* are too little known or too ambiguous to be at present of stratigraphic value. The correlative significance of *Sporangites Jacksoni*, which has not been found elsewhere, is also as yet undetermined. The remaining species which comprise the main body of the Perry flora are Devonian.

As will have been seen in the foregoing review, the evidence of the geologic distribution, so far as known, of the identical species, of the genera themselves, and of the most nearly related plant forms indicates distinctly and overwhelmingly a Devonian age for the Perry formation. The stratigraphic range of most of the species and their allies strongly points to a place in the upper Devonian, the preponderance of the evidence being in favor of the Catskill-Chemung stage. Allowing for the full weight of the two or three species of close lower Carboniferous affinities, the flora can not at latest be assigned to a stage above the upper

[a] As *Dictyocordaites Lacoei* Dn., from the Chemung of Pennsylvania.

[b] *Lepidodendron Gaspianum*, a characteristic Devonian plant, unknown in the Carboniferous, and reported from Perry by Dawson, is omitted from the list as insufficiently represented for identification in the Perry material which I have seen.

Catskill as developed in northeastern Pennsylvania and southeastern New York. Compared with the flora of other continents the closest paleontologic affinities of the Perry flora are found in the plant associations of the Donetz and of the Arctic Devonian.

The occurrence of closely related species of *Barinophyton* and *Leptophlœum* together with *Archæopteris* in the Devonian of Australia affords an interesting example of the remarkable intercontinental distribution of the later Devonian plant types.

The conclusions as to the age of the Perry beds recorded long ago by Sir William Dawson are fully corroborated by the study of more extensive material and the discovery of additional plants. The deposition of the strata antedates all known formations of coal in commercial amounts. Small lenticular beds, streaks, or pockets of coal or coaly matter, of local occurrence only, are, in rare instances, found in beds of so great an age as the Perry, but they are always too thin, if not too dirty, to be of use. There is not even the slightest indication of the presence of such beds in the rocks of the Perry basin. The underlying rocks about Perry are still older.

The supposition entertained by some geologists that the Perry formation is identical with the beds regarded as lower Carboniferous at Lepreau, in New Brunswick, in accordance with the arguments and maps published by a number of Canadian geologists, and that, consequently, beds of anthracite coal like that at Lepreau may be found in another series of beds, which is interpreted by them as underlying and older than the lower Carboniferous, is absolutely untenable for two reasons: (1) The beds supposed to be lower Carboniferous at Lepreau, if their age is correctly determined by the New Brunswick geologists, were deposited later than the formation of the Perry beds, and can not represent the same geological period; (2) the series of beds (Lancaster formation) containing the Lepreau coal and supposed to be older than both the lower Carboniferous and the Perry beds are conclusively proved by their fossil contents to be not only of Carboniferous age, but to belong some distance, at least, above the older portion of the lower Carboniferous. The Lepreau coal, being of later date than the age of the supposed lower Carboniferous, can not stratigraphically underlie the latter except as the result of overturn or overthrust. Otherwise the series of beds supposed to be lower Carboniferous must be of far later date.

In view of the facts (1) that no trace of the much younger geological series which carries coal at Lepreau is found in the Perry basin,[a] and (2) that the coal bed at Lepreau is so thin, altered, and dirty[b] that all attempts to mine or use it were long ago abandoned, any further consideration of the possible occurrence of such a bed in the Perry basin is superfluous.

[a] A condition that is most natural, since that series is of vastly later date of formation. If present, it should *overlie* the Perry.

[b] About 36.88 per cent of ash, fide Rept. Geol. Survey Canada, 1878–1879, p. 13D. For further descriptions of the Lepreau bed, see also Rept. Geol. Survey Canada, 1876–1877, p. 345. The bed consists of streaks of carbonaceous shale with interbedded crushed graphitic coal. All efforts to utilize the material as fuel were long ago abandoned.

CHAPTER IV.

ECONOMIC GEOLOGY.

By GEORGE OTIS SMITH.

HISTORY OF SEARCH FOR COAL.

At the time of the publication of Jackson's first geologic report, in the year 1837, interest in the search for coal in this region seems to have already been aroused. It appears that, as geologist to the State, Doctor Jackson, in accordance with the desire of Governor Dunlap, first devoted his attention to the question of the occurrence of Coal Measure rocks, and visited the Perry district at an early date. No special encouragement was offered in his report to those interested in this subject, but the statement is made: "If coal really occurs in this sandstone, it should be found between the village of Pembroke and the St. Croix River."

Prospecting for coal in the town of Perry is said to have begun in 1837 with work by the St. Croix Freestone Company. Ten or twenty years later one Hill, said to have had experience as a miner, who was attracted by what he considered indications of coal, secured mineral rights from the owners of land in the towns of Perry, Pembroke, and Robbinston. The expectation at first seeming to be that coal would be discovered near the surface, a shaft was dug down to the ledge, but it was found necessary to continue the exploration by drilling. The place selected for the location of the prospect was on the north side of Little River, between the shore and the road leading to Gleason Cove. With the somewhat crude type of drill used progress must have been slow and expensive, but it is reported that a depth of about 400 feet was reached. The loss of the drill and later the death of Mr. Hill caused the abandonment of all work.

The interest of geologists in the Perry fossil locality may have helped to keep alive the local belief in the occurrence of coal beds in the red sandstone formation. Another prospect shaft was sunk on the Brown farm, south of Boydens Lake. This is now covered over and the dump overgrown with trees, so that nothing can be learned of the results of the work, except that typical Perry sandstone and conglomerate make up the dump. Operations began again

in 1893, when W. F. Trask put down a diamond-drill hole to a depth of 604 feet. This was done for a reorganized company, but again the money procured was exhausted before the work was completed. This drill hole was located close to the old Hill shaft. Little can be learned concerning the strata cut by this hole. The reported statements of the same witness at different times are quite at variance as regards the occurrence or nonoccurrence of coal. It is undoubtedly safe, however, to accept his statement that no coal was found.

Mr. Jesse C. Gleason, of Perry, kindly furnished a piece of the drill core, which came from near the bottom of the hole and was said at the time to be "top clay." Below this it was locally reported that coal was found. This piece of core was of special value to the present investigation from its petrographic character. It is a rhyolitic lava, and is plainly the same rock as the Silurian lava exposed in the shore section. This shows that the Trask drill hole penetrated to the base of the Perry formation and even into the Silurian rocks beneath.

At another locality near Perry, it is reported, coal was actually found in the inclosing rock. The place is on Little River, at the upper dam. When the rock was blasted out in the course of constructing this dam by the Eastport Water Works Company in 1892, a "coal pocket" is said to have been exposed. Our own careful examination of the rock at this place failed to show any traces of coal, and the geologic evidence is strongly against the supposition that any was found there. The rock does not belong to the Perry formation, but, as can be seen from the geologic map in this report, is a part of the Silurian series underlying that formation. The Silurian purple shale is here cut by a dike of dark porphyry of the type described on page 28. What was thought to be coal may have been some dark-colored mineral deposited upon the contact of this dike with the shale, since it is most improbable that coal could occur in such association and in rocks of Silurian age.

It is also reported that coal was found in the glacial drift below this dam, where the trench was dug for the water pipe, but this report could not be verified.

This brief historical sketch of the search for coal is sufficient to indicate how little basis there has been for the belief that coal can be found in the Perry basin. It is unnecessary to consider to what extent this sanguine expectation may have been fostered by some for the sake of possible personal gain, but it is evident that the interest shown by students of geology in the Perry beds has had perhaps a greater influence upon the public mind, causing the residents of Perry and adjoining towns to become unusually well versed in geology. It is unfortunate, however, that the suggestions and inferences favoring the occurrence of coal in this area have been so much more quickly grasped than the counter evidence. In the remaining portion of this chapter the geologic evidence on this economic subject will be presented.

GEOLOGIC DATA.

Brief mention has already been made of two cases in which the reported occurrence of coal is opposed by geologic observations. To serve the purposes of this report, however, it is advisable to cite more fully these geologic data and to explain their application to this subject. It is believed that when the evidence is fully stated the reader will be able to form a definite opinion regarding the possibilities of finding coal in the Perry formation. The fact that during all these decades in which the interest has been maintained in this question so little regard has been paid to certain fairly obvious features of the local geology renders it all important that at this time the geologic data should be explicitly presented.

The character of the Perry formation has been described in a preceding section. The rocks of this formation comprise volcanic products, such as lavas and breccias, and sediments of the coarser type, such as conglomerates and sandstones. Professor Bailey of the Canadian Survey and Professor Shaler of Harvard University have compared the Perry formation to the Catskill of the New York section. This comparison probably expressed not only their belief regarding the age of the formation, but also a recognition of the general resemblance of the Perry rocks to the red sandstones of the Catskill formation. It may be noted that these two formations are not only similar in color, but both are remarkably free from black carbonaceous beds of any kind. In view of the excellent exposures of the Perry beds along the shore it is extremely improbable that any part of the section is concealed. The deep indentations in the coast line cause the same beds to be repeatedly exposed, and therefore a thin stratum that might be concealed in one place would quite likely be shown at another. The fact that no black shales were observed in any portion of the section may, therefore, be taken as strong evidence of the absence of coaly beds in the Perry formation.

As is well known in coal regions, coal seams usually occur in association with under-clays, but no such beds are observed in this area. This absence of fire clays in the section may be regarded as evidence that the physical conditions existing during the time the Perry sediments were being deposited were not favorable to the accumulation of vegetal matter in the form of coal seams. The conglomerates and coarse sandstones, which frequently are cross-stratified, represent sediments laid down in an estuarine basin, where coarse material was contributed by large streams and deposited close to shore. Only rarely did the plant fragments washed down from the land find lodgment in sediments sufficiently fine grained to preserve them as fossils.

Another geologic condition that did not favor coal accumulation was the

volcanism that characterized the Perry epoch. Volcanic activity had been a feature in this area during the Silurian period, and was renewed during the time of the deposition of the Perry rocks. From some volcanic center in this vicinity lava flows were erupted, so that sheets of basalt and associated beds of volcanic ejectamenta now occur interstratified with the sandstones and conglomerates.

But perhaps the most conclusive data on this subject of the possibility of the occurrence of coal in the Perry formation are connected with the question of geologic age. The assignment of a Triassic age to these rocks by the first geologists who visited the region, and in later years the correlation of the Perry beds with Carboniferous rocks of New Brunswick, have both served to foster the belief in the possibility of finding coal. The determination of the exact age of this formation, therefore, has become a matter of prime importance. The results of the paleobotanical investigation, as stated in this report, point to the Devonian age of the Perry formation. Rocks of this age are known in certain districts to contain local accumulations of carbonaceous matter, it is true, but such coaly streaks or lenses are thin—rarely a foot in thickness—and of very limited area. Therefore it can be stated that nowhere are rocks of the same age as the Perry beds repositories of commercially workable coal.

There are several instances reported in the Perry region of old coal miners, or self-termed mining "experts," basing very strong opinions upon the fossil plants found at Perry. The similarity of these plants to those associated with the coal at Springhill, Nova Scotia, or with the Pennsylvania coal, has been remarked upon and definite conclusions have been inferred. The identification of Paleozoic plants involves much more critical study than is commonly understood, and little credence should be given to the observations and deductions of those who do not appreciate the complexity of the subject.

Another line of evidence is afforded by the stratigraphy of this area. It will be noticed that all of the prospects and reported occurrences of coal are near the southern border of the area of the Perry formation. The waterworks dam is in fact near the contact with the older rocks, and the rocks in which coal is reported to have been found do not belong to the Perry formation, but are of Silurian age. Both the Hill-Trask and the Brown prospects were located within a half mile of the contact with the Silurian rocks. Such a location, taken in connection with the low dip of the Perry rocks at those points, means that the base of the Perry formation is not many hundred feet beneath the surface. In fact, we have conclusive evidence that in the Trask hole, as stated on a previous page, the drill actually reached this basal contact and penetrated for some distance the underlying Silurian strata. The piece of core termed "top clay" by the driller is in reality a rhyolitic lava. The similarity of this to the lava which occurs interstratified with the Silurian fossil-

iferous rocks south of Gleason Cove was noticed in the field, and subsequent microscopic study has verified this identification. It is a fortunate as well as interesting fact that the Silurian and Devonian lavas are of such diverse types. On this account there can be no doubt that the Trask drill hole cut all the strata in which there was believed to be any possibility of encountering seams of coal. In fact, it cut even some of the lower beds, including this lava sheet, which is known from its petrographic character to be of Silurian rather than of Devonian age.

CONCLUSIONS.

From all the foregoing facts, therefore, it must be concluded that the belief in the existence of coal in the Perry formation, although maintained for nearly seventy years, is not supported by geologic evidence. The composition of the rocks comprised in this formation, as studied in satisfactory sections, neither shows the presence of any carbonaceous beds nor favors the possibility of their occurrence in concealed portions of the section. This conclusion that coal is not present in the formation is furthermore strongly supported by deductions based upon the Devonian age of the Perry formation, as determined by paleobotanical studies.

Exploration work in these rocks has failed to show the presence of coal seams, and the force of this statement is strengthened by the knowledge that the Trask drill hole reached the base of the Perry formation. Continuation of the work there, or drilling at a locality near the reservoir dam, would simply result in expensive exploration of Silurian rocks in which no one conversant with coal mining would expect to find coal. In fact, a drill hole at the latter locality, though it is reported to have been proposed on the recommendation of an expert, would have resulted only in an utter waste of money.

The assignment of a Devonian age to these rocks may suggest the possibility of finding oil or gas in the Perry area. On this point it need only be stated that the outlook is no more encouraging than that for coal. The occurrence of joints and faults, such as have been described in this report, as well as the presence of interbedded lava flows, are most unfavorable indications, since they preclude the conservation and storage of any liquid or volatile hydrocarbons, even had they originally been present.

The practical deduction to be drawn from the results of the geologic study presented in this report is that further exploration of the Perry basin for coal is unwarranted.

APPENDIX.

COAL IN OTHER LOCALITIES IN MAINE.

By George Otis Smith.

GREENFIELD.

Another locality where coal indications have been reported is the town of Greenfield, the second town east of Oldtown, Me. The rocks exposed in this vicinity differ slightly from the slates seen along the Penobscot River. Red and black slates are the predominant rocks exposed in Greenfield, where the search for coal has been prosecuted. It is in the black slate that what has been termed coal has been found. The black slate is, in places, sufficiently carbonaceous to soil the fingers, a character that immediately suggests soft coal, and the bright glistening surfaces of the rock, as seen in excavations, make it also resemble anthracite coal. Near Myra post-office a large shaft has been sunk to a depth of about 20 feet, but in September, 1903, the time of the examination, this opening contained 10 feet of water. The observations possible in the upper portion of the shaft, as well as the examination of the rock which had been thrown upon the dump, were sufficient to give a good idea of the character of the material that is traversed by this shaft. The brilliant luster of much of this rock is plainly the result of crushing and slipping within the rock mass. Similar bright surfaces, technically termed "slickensides," occur in rock of any kind that has been subjected to extreme dynamic action, and in a black rock, like the slate in Greenfield, the resemblance to anthracite coal becomes very strong. It is when these slickensided pieces of slate are broken across, however, that the true character of the rock is seen. The slate is of a dull gray color, and is quite unlike either bituminous or anthracite coal. The rock is full of quartz seams and gashes, which afford further evidence of the crushing to which the slate has been subjected.

The resemblance of this material to coal was the basis for the beginning of prospecting in this locality, and this indication was later supported by reports that the coal had been successfully burned in a blacksmith's forge and used in grates. It is unnecessary to consider the source or truth of such reports after examining the black slate to which they refer. The rock is plainly carbonaceous, but, as is

shown above, it is not sufficiently so to make the resemblance to coal at all close. For the purpose of thoroughly testing the material, however, a determination of the percentage of carbon in this rock was made in the laboratory of the United States Geological Survey. The loss on ignition in a selected sample of the best material from Greenfield was found to be 9.2 per cent. The remaining 90 per cent of the rock would correspond to what is termed ash in a true coal. This is sufficient to show that the black rock which has been prospected in Greenfield is in no sense a coal, even of the most impure variety, and the geologic examination of the locality affords no warrant for further exploration for coal in the formation exposed there.

FISH RIVER.

It was reported to the Maine Survey Commission that coal had been found on the line of the Fish River extension of the Bangor and Aroostook Railroad. The locality where the coal was said to occur was within the region where Silurian and Devonian strata were recognized at the time of the early surveys of the State, so that there appeared to be a possibility that the Carboniferous might also be represented. Therefore, in accordance with the instructions, a trip was taken over this line and the locality was visited. The examination of the rocks along the railroad was greatly facilitated by the courtesies extended by the officials of the Bangor and Aroostook Railroad.

The strata are well exposed in the fresh cuts of the recently constructed railroad, many of the beds thus exposed probably not being visible in natural outcrops. The formation exposed near the Fish River bridge south of Eagle Lake comprises sandy and shaly beds. These are soft and appear younger than the limestones and other rocks that are exposed both north and south of this locality. The reported "coal" was found to be a 3-inch seam of black material, interbedded with the sandstone and shale. In composition this is simply a shale in which there is sufficient carbonaceous material to give it a black color. It is not coal, and the reports that it had been successfully used in a blacksmith's forge were easily nullified by testing the shale in a hot fire. Pieces of the rock thus treated can be slightly bleached by the action of the fire, but can not be ignited.

This black shale and the associated strata contain fragments of plant remains, a small collection of the best of which was sent to Mr. White for study. His report is as follows:

"The fossil plant material from Fish River consists of small fragments, which, unfortunately, were so triturated and abraded before deposition as generally to obliterate their external characters. Among the specimens are some which appear to represent *Psilophyton elegans* Dawson. Others are doubtfully referable to *Psilophyton princeps* Dawson. The presence of these plants is strongly indicative,

though not conclusively demonstrative, of a Devonian age for the beds. No recognizable traces of the genera *Archæopteris* or *Lepidodendron* are noticeable. The absence of these, if the collection is thoroughly made and representative, constitutes negative evidence for a reference to an earlier Devonian stage; but the weight of such evidence is little unless the observations are somewhat ample. The characters preserved in the specimens are, on the whole, such as to leave little room for doubt as to the reference of the Fish River beds to the Devonian."

OTHER LOCALITIES.

At three other localities in the State an attempt was made to verify the reports of the occurrence of coal. The first of these was in the extreme southern part of the town of Penobscot, where some prospecting has been done in a black slate. The rock here is similar to that at Greenfield, but probably contains even less carbonaceous material. The slate is contorted and seamed with quartz, and possesses so little of the appearance of coal that it is strange that it should be considered of any value.

Another region where the occurrence of coal was reported to the commission is Cape Elizabeth. Pieces of coal are said to have been picked up in a plowed field at one place from time to time for a number of years. Unfortunately all of these fragments had been given away or burned, and no others were found in our examination of the field. The country rock, however, at this locality is the same schist that is exposed elsewhere throughout this region. In another part of this town coal is said to have been found when excavations were made for laying water pipes. A piece of this material was seen, and was readily determined as compact black slate rather than coal.

The third locality is Madrid, where anthracite coal was reported to outcrop close to a house. Prof. Leslie A. Lee, State geologist, visited this locality, only to find that the coal was not in place but was fuel that had been left on the property previous to its occupation by the present owner.

Newspaper accounts mention other towns in Maine as promising localities for the occurrence of coal, but in each case the probabilities are that black shale or graphitic slate has been mistaken for coal.

PLATE II.

PLATE II.

PLATYPHYLLUM BROWNIANUM Dn.

(Page 37.)

FIG. 1. Original specimen illustrated by Sir William Dawson and now in the collection of the Boston Society of Natural History, through whose courtesy it is here refigured.

FIG. 2. Another example, more deeply dissected. Collection of the Portland Society of Natural History.

OTIDOPHYTON HYMENOPHYLLOIDES D. W.

(Page 47.)

FIG. 3. Example showing the umbilical impressions at the bases of the sinuses, and indications of obscure depressions, with thickened carbon near the apices of the lobes.

DIMERIPTERIS RECURVA (Dn.) D. W.

(Page 56.)

FIG. 4. Bifurcating branchlet.

FIG. 5. Fragment illustrating the bifurcation of the small lobes.

FIG. 6. Specimen with more deeply dissected lobes, whose aspect is suggestive of a bivalvate capsule.

DIMERIPTERIS INCERTA (Dn.) D. W.

(Page 53.)

FIG. 7. Example showing the rapid subdivision of the lamina in different planes, the ramules provided with clustered sporangia.

FIG. 8. Fragment showing fragment of major division with dilated thin lamina of the branch, which is fertile.

FIG. 8a. Enlarged four times the natural size, showing one of the sporangia illustrated in Fig. 8.

FIG. 9. Specimen illustrating the rapid subdivision of the ramules in proximity to a branch of considerable size.

TÆNIOCRADA PALMATA D. W.

(Page 37.)

FIG. 10. Portion of frond showing dissection of the lamina, the lobes of which are traversed by very thin axes of greater density.

BARRANDEINA PERRIANA (Dn.) D. W.

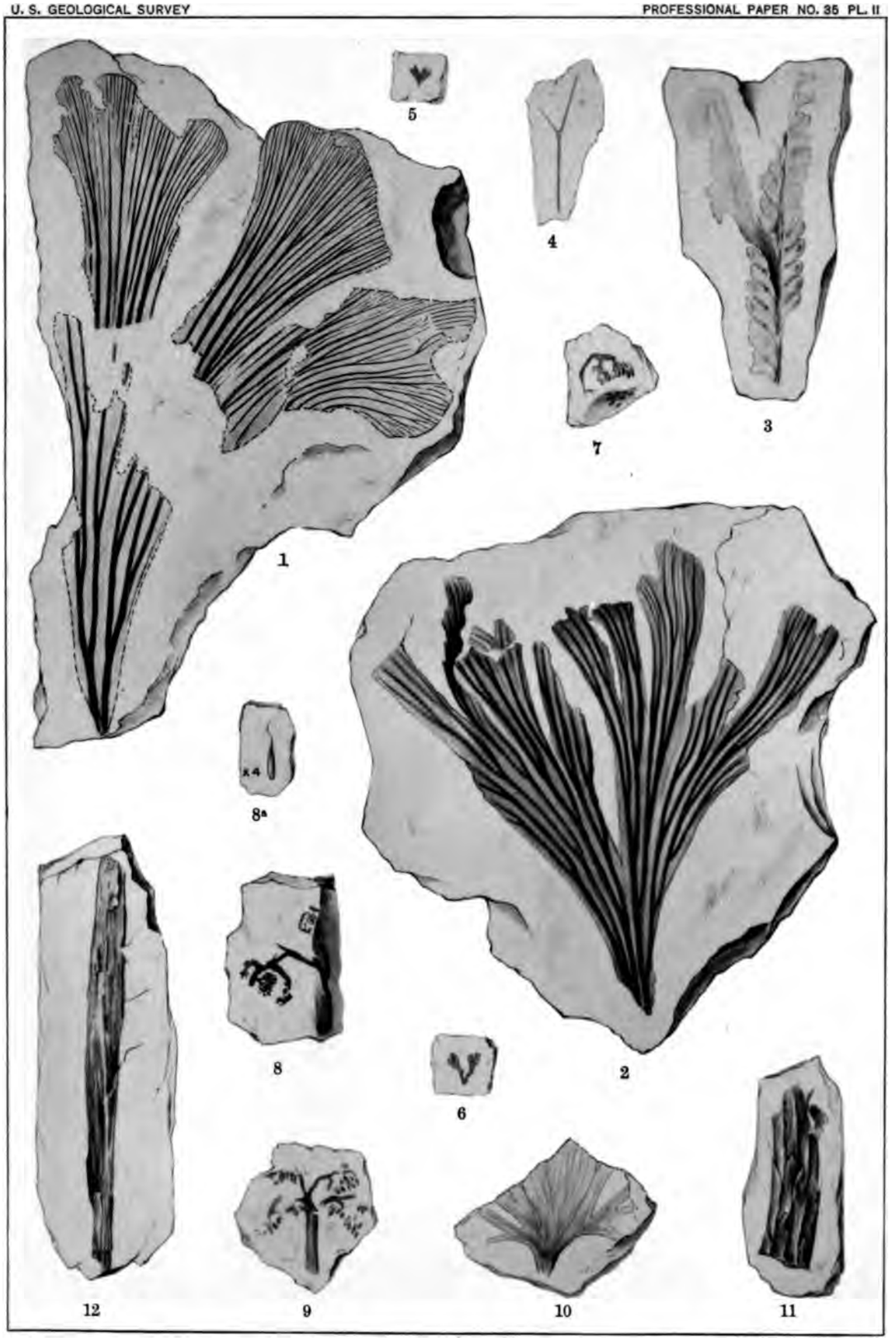
(Page 49.)

FIG. 11. Fragment of stem showing the extremely decurrent petiolar bases descending along the axis in spiral arrangement, though frequently broken back to different levels.

ARCHÆOPTERIS ROGERSI Dn.

(Page 43.)

FIG. 12. Rachial fragment showing corrugation of the descending petiolar bases.



FOSSILS OF THE PERRY FORMATION

PLATE III.

PLATE III.

ARCHÆOPTERIS JACKSONI Dn.

(Page 39.)

FIG. 1. Fragment of frond showing characteristic arrangement and aspect of the pinnæ, the rugose rachis with vestiges of rachial pinnules, and the imbrication of the ordinary pinnules, which in this example are slightly broader than is usual. Figured by courtesy of the Portland Society of Natural History, in whose collection the specimen now rests.

FIG. 2. Fragment of the common type of pinna found in the formation, illustrating the typical rather narrow imbricated pinnules.

FIG. 2ª. Twice the natural size. Pinnule of the example shown in Fig. 2 enlarged to show the outline and nervation, which is really derived from a dense primary fascicle descending along the rachis.

FIG. 3. Fragments of extraordinarily broad and apically rounded pinnules of the same species.

FIG. 4. Portion of a fertile pinna of the form described as belonging to the species, but possibly representing an early stage of the fertile pinna of *A. Rogersi*.

ARCHÆOPTERIS ROGERSI Dn.

(Page 43.)

FIG. 5. Portion of a fertile pinna showing the fasiculately attached sporangia and the prolonged midrib of the pinnule.

FIG. 5ª. Twice the natural size. Detail from Fig. 5 showing the fasciculate arrangement and the thickened neural line of the sporangium.

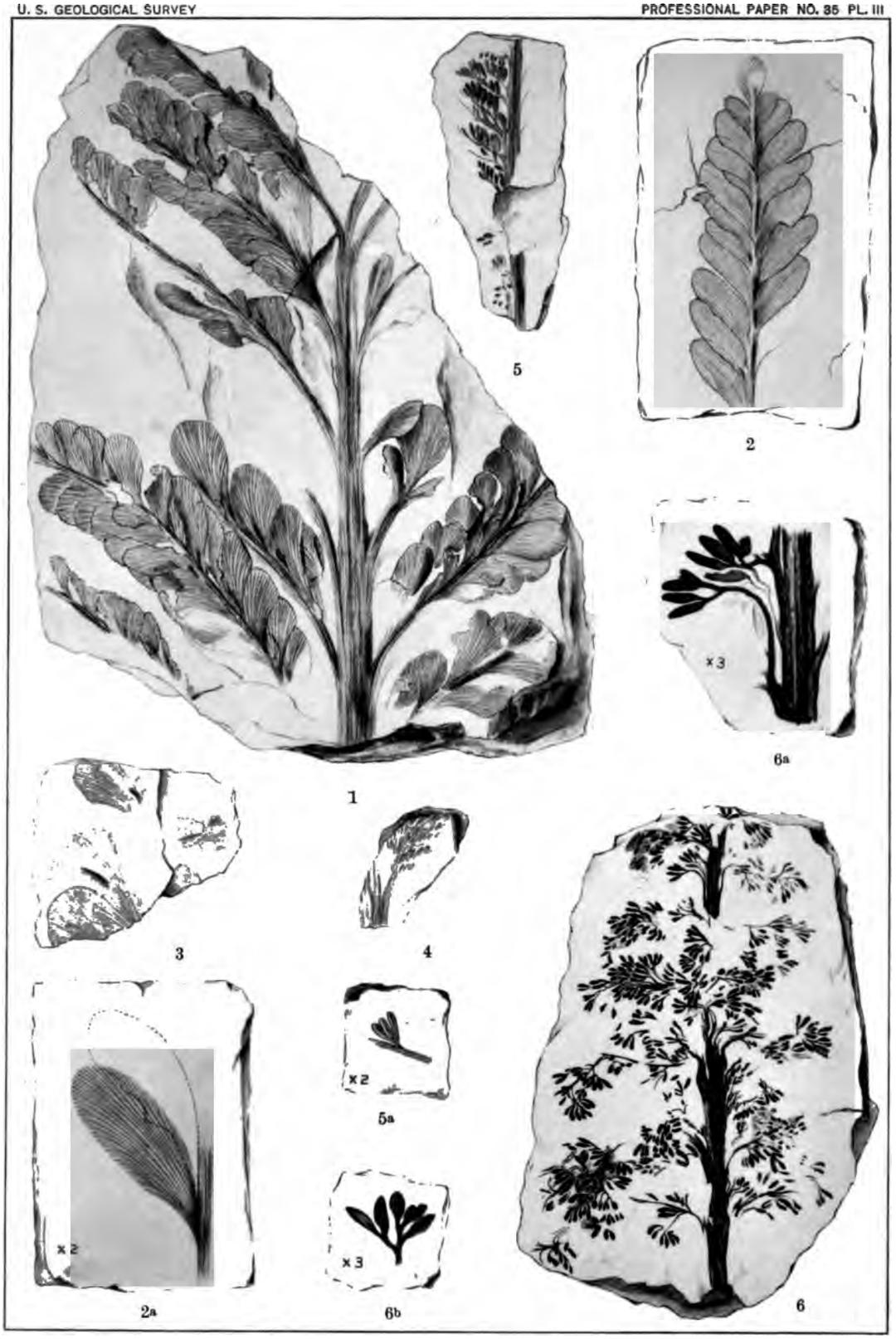
ARCHÆOPTERIS HITCHOCKI (Dn.) D. W.

(Page 45.)

FIG. 6. Original type of the species, No. $\frac{43,29}{1}$ in the fossil plant collection of the American Museum of Natural History, through whose courtesy it is here refigured. The specimen shows clearly the sporangial nature of the ultimate divisions, the entire segment being fertile and reduced in lamina.

FIG. 6ª. Three times natural size. Showing sporangia attached to nerves of reduced rachial pinnules in the upper part of the specimen shown in Fig. 6.

FIG. 6ᵇ. Three times natural size. Showing the arrangement of the sporangia in the peripheral portion of the specimen.



FOSSILS OF THE PERRY FORMATION

PLATE IV.

PLATE IV.

RHACHIOPTERIS PINNATA Dn. var. ANGUSTIPINNA D. W.

(Page 50.)

FIG. 1. Fragment of the rachis, showing mode of opposite division, the decurrent bases of the subdivisions, and the slender vascular axes of the latter. Vestiges of extremely tenuous laminar appendages, probably representing the leaves of the species, are seen on the larger branches.

FIG. 2. Fragment of a smaller example, showing the dilation at node on the main rachis opposite and between the lateral divisions. This feature also appears, though less distinctly, in Fig. 1.

FIG. 3. Slender branchlet with vestiges of leaves.

PALÆOSTACHYA ? Sp.

(Page 64.)

FIG. 4. Fragment of axis showing basal portion of scales, in the axils of which appear to be grouped sporangia whose mode of occurrence and probable arrangement are suggestive of *Palæostachya* One of the bracts, broken in the process of preparation of the specimen, was over a centimeter in length.

BARINOPHYTON RICHARDSONI (Dn.) D. W.

(Page 64.)

FIG. 5. Fragment of rachis, showing several of the boat-shaped branches or pinnæ still attached, the arrangement being probably spiral. Collection of the Portland Society of Natural History.

FIG. 5ª. Detail, enlarged twice the natural size, showing the lobes or pinnules of the upper pinna on the right-hand side of Fig. 5. The midribs are somewhat depressed. The depressions at the base of lobes are not well shown.

FIG. 6. Another example showing the pinna in a more advanced stage of development. The apices of the lobes are generally obscure and their full length is not usually clear. In the second branchlet from the base on the right the rachial depressions are shown, the lobes being in part broken away on the side toward the observer.

FIG. 7. Fragment of a full developed or old pinna representing the condition originally figured by Dawson as *Lepidostrobus Richardsoni*. In this example the thick, fleshy rachis is well exhibited, the lobes being apparently attached just within the margin on the ventral surface of the broad wing of the rachis. Collection of the Portland Society of Natural History.

FIG. 8. Elongate and straightened pinnæ probably belonging to the same species and representing a stage comparable to that seen in Fig. 5.

FIG. 9. Fragment of very young branchlet spread out.

BARINOPHYTON PERRIANUM D. W.

(Page 68.)

FIG. 10. Fragments of several pinnæ, the two on the left being in their original position.

FIG. 10ª. Enlarged twice the natural size. Detail of the lower pinna in Fig. 10, showing the form of the lobes and the depressions or pits, presumably sporangial, at the bases of the latter.

CARPOLITHES CONFINIS D. W.

(Page 78.)

FIG. 11. Isolated seed, showing striate surface and broad basal attachment.

LEPIDOCYSTIS INQUISITUS D. W.

(Page 75.)

FIG. 12. Broad form of the sporangium.

FIG. 13. Short-ovate form.

FIG. 14. Elongate form, which, like the others, is slightly crescentic.

FOSSILS OF THE PERRY FORMATION

PLATE V.

PLATE V.

PSILOPHYTON (?) ALCICORNE D. W.

(Page 64.)

FIG. 1. Example showing the anomalous type of ramification appearing on one side only of the axis. A third branch on the right, similar to the upper one in the figure, was originally seen on the specimen, but was destroyed in the process of clearing the matrix from the fossil.

FIG. 2. Another example, slightly larger and more complicated, though the primary system is similar to that shown in Fig. 1.

?PSILOPHYTON CF. PRINCEPS Dn.

(Page 58.)

FIG. 3. Fragment showing the ordinary flexuous rachis, irregularly sulcate with one or two somewhat irregular, broadly rounded ridges. The abrupt termination of the branches at a little distance from the rachis, as shown in this figure and Figs. 4 and 6, is characteristic of this type of fossil.

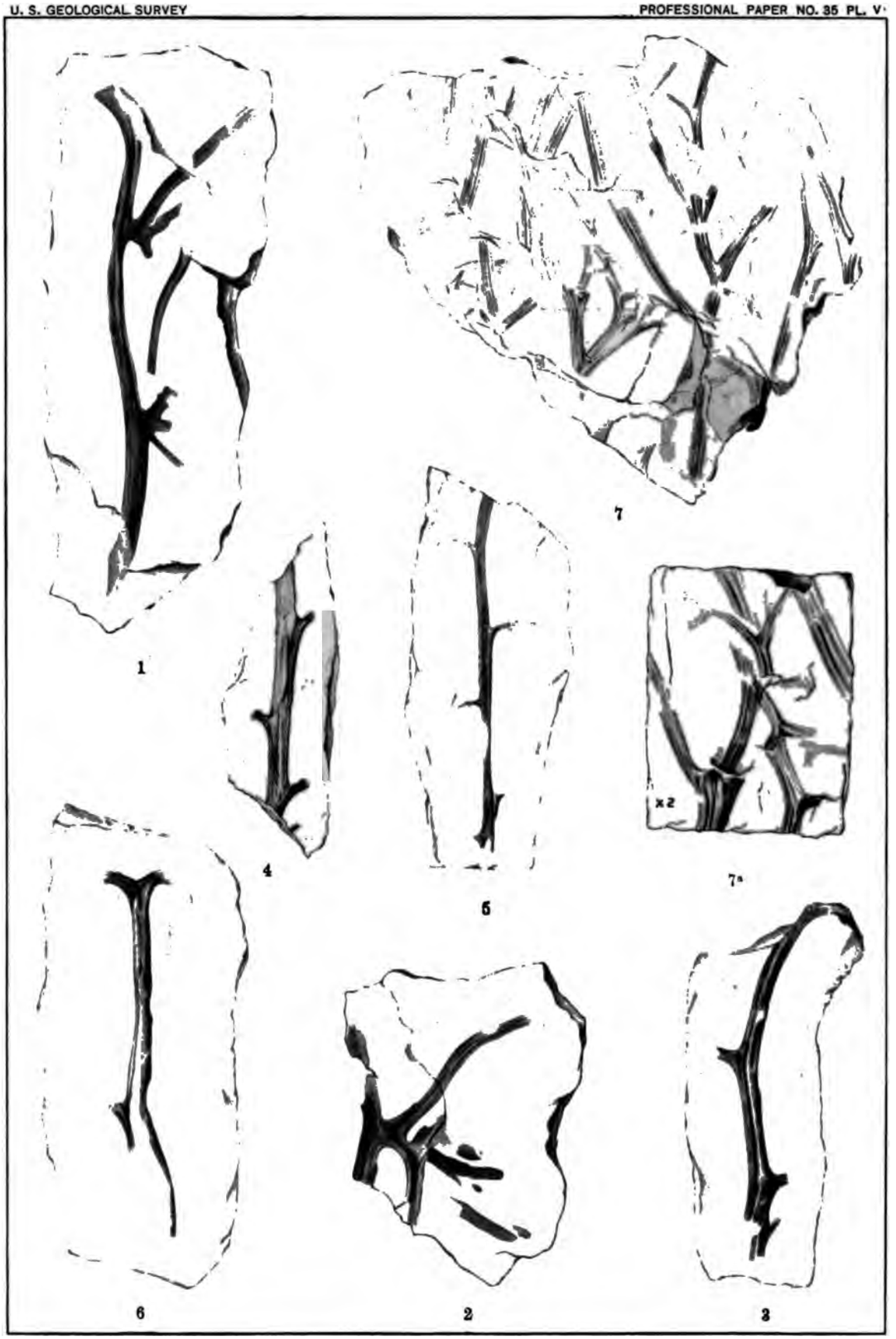
FIG. 4. A similar fragment in which the somewhat elongated depressions appearing on the base and just within the terminations of the rameal vestiges are more clearly shown. The abrupt terminations are probably due to the almost abrupt change from the rigid axial structure to the thinner and more delicate ramose laminar structure of the foliage.

FIG. 5. A more slender axis, with fragments of the foliate ramules still attached.

FIG. 6. Example showing the bifurcation of a rachis at the top, with indications of the immediate dichotomy of each of the subdivisions. At the same time the axis curves backward, and the subdivisions are not in the same plane with the parent rachis. The abrupt termination in the fossil of the two main subdivisions at the top of the rachis is exactly comparable to that of the lateral branches shown in Figs. 3 and 4.

FIG. 7. Specimen from Campbellton, New Brunswick, in the collection of the United States National Museum, labeled by Sir William Dawson as *Psilophyton princeps*. The costation is distinct in the fragments of rachis, some of which show an irregular form of ramification, somewhat similar to that illustrated above under *Psilophyton? alcicorne*. A few of the fragments in the specimen shown in Fig. 7 are obscurely and distantly punctate. The ultimate divisions of the plant are extremely delicate, and, owing to the irregular mode of division by which they are intermingled and to the fact that they do not lie in the same plane, they are generally very imperfectly exposed.

FIG. 7a. Twice the natural size. Central portion of the original of Fig. 7, showing more clearly the costation of the rachis and the mode of subdivision of the tenuous foliar laminæ.



FOSSILS OF THE PERRY FORMATION

PLATE VI.

PLATE VI.

LEPTOPHLŒUM RHOMBICUM Dn.

(Page 69.)

FIG. 1. Original type of the species, No. $\frac{4804}{1}$ in the fossil plant collection of the American Museum of Natural History, through whose courtesy it is here refigured. The example shows the normal bolsters in the lower portion, those in the middle being more or less disfigured by a transverse wrinkling of the epidermis, the wrinkles being curved between the points of resistance offered by the lateral angles and the leaf scars of the bolsters, so that in the upper middle the boundaries of the latter are partially obliterated. This transverse wrinkling, which, it will be seen, is apparently of superficial origin, was responsible for the description of this specimen as containing a chambered pith identical with *Artisia*. It will be observed that above the shriveled and wrinkled central portion the bolsters are resuming their normal size and form.

FIG. 2. Example illustrating the large size of some of the bolsters, in the apices of which occur the pore-like ligular pits.

FIG. 3. Fragment of an impression, the relief of the bolsters being exaggerated. In this example the leaf scars are slightly above the middle of the bolsters.

FIG. 4. Crushed and slightly macerated specimen in which the surface features of the bolsters are shown near the margins, while throughout the central portion the impressions of the intracortical and subcortical structures only are seen, the superficial tissues having been removed. The central strand curving irregularly within the cylinder of the much macerated inner cortex of the fragment probably represents the woody stele of the stem. Its nodation is the result of impression on the more rigid rhomboidal cortical tissues.

LEPIDOSTROBUS GLOBUSUS Dn.

(Page 73.)

FIG. 5. The specimen agrees in general features with that originally figured by Dawson.

FIG. 5^a. Enlarged four times the natural size. Showing the curvature of the scales, each of which is traversed by a nerve strand and is convex in the outer portion.

SPORANGITES JACKSONI D. W.

(Page 76.)

FIG. 6. Portion of the contents of a large, elongated sporangium or possibly of two superimposed sporangia, consisting of a slightly brownish mass more or less crowded with the dark carbonized megaspores. The original is in the collection of the Boston Society of Natural History, through whose courtesy it is here described.

FIG. 6^a. Enlarged eight times natural size. Details showing some of the megaspores from the original of Fig. 6.

? PSILOPHYTON CF. PRINCEPS Dn.

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FIG. 7. Specimen showing a trifurcation of the axis, the two subdivisions in the foreground being comparable to that shown in Fig. 6 of Pl. V, the middle subdivision springing from the back side and lying in a different plane.

FIG. 8. Fragment probably belonging to the same species, showing the rapid ramification near the periphery of the plant, the branchlets appearing as abruptly terminated, possibly as the result of abrasion of the more delicate laminæ.

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5a

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6

FOSSILS OF THE PERRY FORMATION

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[Black-face figures indicate pages on which detailed descriptions occur; italic figures indicate illustrations; names in italic are synonyms.]

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O

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Professional Paper No. 35.]

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